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Industry
(1819-20)

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by
ABRAHAM REES

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Forge

FORGE, properly speaking, is any kind of furnace, the heat of which is afforded by the action of bellows. The term, however, is now more particularly applied to the common smith's forge, and to the forge used for the manufacture of bar iron. For a description of the latter, see **IRON**.

A peculiar species of forge is also used for the manufacture of shear steel; for an account of which, see **STEEL**. The common smith's forge requires bellows of different kinds and sizes, agreeable to the nature of the work.

The double bellows are chiefly used for the working of iron, and single ones for steel. The double bellows are apt to blow some time after the workman takes out one of his irons; and as in working steel, the heat is less than that employed for iron, the rod of steel, if left in the fire, would be often liable to be burred, as the workmen term it. The single bellows are, therefore, better adapted for this work, because the blast does not continue after the workman leaves the bellows.

The fire-place is generally a flat hearth, nearly on a level with the blast, on which the fuel is placed, which mostly consists of the coaks of pit-coal. In smithery, however, and more particularly for the working of steel, the coal should be carefully selected, as free from pyrites as possible, as the sulphur of that substance is found to be very injurious to the metal. In all cases where welding is required, the sulphur totally prevents the adhesion. If pyrites should by accident get into the fire, the best means to get rid of it is to throw a quantity of iron-silings into the fire, which immediately takes up the sulphur.

After the coaks have been used for some time, the pieces become exceedingly small, and are so light as to be blown away by the bellows, separating the fuel from the iron. This inconvenience is removed by taking away these small particles from time to time. It, however, may be much easier removed by a contrivance which is not in general use. This is effected by making the bed of the hearth a grate, about four inches below the level of the blast. The small dust, passing through the grate upon an inclined plane, is carried away, leaving nothing on the hearth but the proper fuel.

In most of these forges, particularly where great heat is required, the nozzle of the bellows is not presented to the fire. A thick iron tube is placed between the bellows and the fire, called the *tuiron*. It is funnel-shaped at the end next the bellows, for the reception of the nozzle of the bellows; and has a cylindric hole, from about the middle to

the opposite end, a little less than the aperture at the nozzle of the bellows.

Before means were contrived of preventing the *tuiron* from being raised above a certain temperature, it was very speedily worn out by the heat and the oxydation of the iron. This evil has been removed by the invention of what is now called the *water-tuiron*. It consists of something like the common *tuiron*, having a crooked tube passing through the body of it. One end of the tube, at some distance from the *tuiron*, is inserted into the bottom of a tub, filled with water; the other end coming from the *tuiron* passes over the top of the tub: so that the cold water has constant access to the body of the *tuiron*, which the heat of the fire raises into vapour. This vapour passes up the other tube, which condensing, is discharged into the tub. By this means, it is evident that the *tuiron* can never much exceed the heat of boiling water. This contrivance prevents a much greater evil than the destruction of the *tuiron*. The oxyd of iron, which is constantly formed from the heated iron, combining with the earthy matter of the coal, forms a very fusible scoria, which, if the *tuiron* were not kept cool, would be apt to adhere to it, and stop up its aperture. This scoria may be easily discharged through the grate of the hearth, which would at any rate be an interruption to the blast.

The large quantity of oxygen constantly blown into the fire, upon the iron, at so high a temperature, causes a very rapid oxydation of the metal. This oxyd has some tendency to vitrification, and consequently to prevent the iron, in some measure, from the future attacks of oxygen. Since, however, flux forms a very fusible vitreous compound with the oxyd of iron, the smith is in the habit of using the powder of any stone of a sandy nature. When the iron becomes nearly of a welding heat, he takes it out to immerse it in the powdered sand. A thin fluid substance is immediately seen to flow over the heated surface, which defends the metal from the oxygen. In the welding of one piece of iron to another, the use of sand is highly important, and more particularly in welding steel to iron. When the two surfaces are brought together, the oxyd of iron, with the flint, is removed by reason of its great fluidity. If, however, the oxyd were not rendered thus fluid, it would remain and prevent the adhesion of the surfaces.

Lead is found to be very injurious to the smith's fire; it combines with something on the surface of the iron, which makes it unfit for welding. Its presence is easily known, as the iron affected with it makes a brown mark upon the

FORGE

anvil. The strongest heat of a forge is at about two inches from, and a little above the aperture of the furnace.

A forge is also used by braziers, copper smiths, and in the plated manufactories. This consists of a hearth like the smith's forge, and a pair of bellows. The fuel is mostly coal, but sometimes for particular purposes charcoal. It is used for annealing their metal previous to working it, and also for folding.

The forge fire is not well calculated for the fusion of metals, since the side of the crucible next the blast is liable to be cooled, which generally causes it to break. The portable blast furnace is however better adapted than the common forge, as the air is introduced at bottom, like the common air furnace. See FURNACE.

Forging consists in changing the form of such malleable metals as may have been heated for that purpose in the fire of the forge, by means of the hammer and other instruments used in smithery.

Several of these processes are carried on by machinery worked by water or steam. In the manufacture of bar iron, very large masses of this metal, called blooms, are drawn into bars by an immense hammer, worked by a water wheel, or the steam-engine. See IRON.

The forging of scythes is also performed by similar power, which by the workmen is called skelping. See SCYTHE.

Forging, however, more properly belongs to the forming of various utensils from iron, and other malleable metals.

The anvil, on which the metal is laid, consists of a large mass of wrought iron, faced with hardened steel, and ground smooth on the surface. The hammers are of the same materials, and are of different sizes, agreeable to the nature of the work. If the work is heavy, besides the person who holds the substance to be hammered, a second, and sometimes a third and fourth person strike in turns at the heated body. If the body requires to be made round, instruments called *swages* are employed. They consist of two masses of iron faced with steel, and hardened, one lying upon the anvil, or fastened into a groove in the anvil, and the other held in the hand, by means of a piece of hazel stick twisted round it. In the faces of each of these swages a proper sized groove is made, which, for swaging round bodies, is a segment of a cylinder. The body to be swaged being laid upon the lower one, the upper swage is placed upon it, on which a person strikes with a large hammer, while the body to be made cylindrical is turned round. A variety of other instruments are used according to the nature of the work to be done. Iron admits of being forged with greater facility than steel, as it is much softer, and can be heated to a much greater heat, which still makes it softer. Indeed iron is generally heated to a welding heat, in order that its parts, which are frequently loose and unconnected, may be made found.

Copper may be forged into any shape, but will not bear more than a red heat, and of course requires to be heated often. The bottoms of large boilers are frequently made by a large forge hammer worked by machinery. The bolts of copper used for ships, and other purposes, are mostly made by the hammer. Silver, gold, and platinum will also admit of forging into any form. Of the former metal, silver knives are made very neatly by the hammer. The heat at which it is worked should be barely that of ignition.

It is remarkable that alloys of the malleable metals, although very malleable when cold, will not bear the hammer when heated.

FORGE is also used for a large furnace, wherein iron ore, taken out of the mine, is melted down.

But this is not so properly called a forge as a *furnace*; which see.

FORGE is more properly used for another kind of furnace wherein the iron ore, melted down and separated in a former furnace, and there cast into sows and pigs, is heated; and fused over again, and beaten afterwards with large hammers, and thus rendered more soft, pure, ductile, and fit for use.

Of these forges there are two kinds, which the iron successively passes through, before it comes to the smith.

The first is called the *finery*, where the pigs are worked into gross iron, and prepared for the second, which is called the *chafery*, where it is farther wrought into bars fit for use.

FORGE-mills. See MILL.

FORGE-rolant, or *Flying forge*, means such an arrangement of the several implements and materials, necessary for the establishment of a smith's forge, within a cart or waggon, as may qualify it to accompany an army during a campaign, with the same facility as the several carriages appertaining to the train of artillery.

It will be immediately understood, that much contrivance, and great attention to regularity, are necessary to accomplish and preserve so essential a purpose; the more so, as the whole weight of the forge and its supplies of fuel, &c., should not exceed half a ton when conveyed in a cart; nor a whole ton when carried in a waggon. The best mode is to place the anvils and their blocks in such a position as to balance well, but to be easily lifted in and out. For minor purposes two or three small anvils may be attached temporarily to the hinder transom of the cart-body. There should be a water trough, a furnace, and a pair of bellows, all within a frame of iron plate, properly rivetted and closed with hard solder, so as to be firm, and to prevent latent sparks from setting fire to the machine, or to its contents. The tail-board should let down to a level with the bottom of the cart, and be suspended in that direction by strong segments of iron; so as to be well fixed, and to resist pressure either upwards or downwards; the sides around the furnace and bellows ought to be divided into compartments for the reception of fuel, (generally charcoal,) sufficient for immediate service, and for the assortment of nails, screws, bolts, rivets, pins, nuts, horse shoes and nails, bridle chains, buckles, &c., in small quantities, so that any thing wanting immediate repair may be fitted without the smallest delay.

Every forge should carry implements sufficient to employ forty men; of whom two should be fire-men, six sledge-men, ten light hammer-men, two screw and nut-men, and the residuum, side-men, or workers on cold metal. If the apparatus be carried in a waggon that can contain two double forges, or furnaces, double the number of men may be employed; small anvils, in either case, as also vices, being made to screw, or to hook, on to the ends of the several projecting transoms, and even to the naves of the wheels, of which the iron tires become useful for light hammer work. The total weight of a forge-waggon, exclusive of its contents, should never exceed 15 cwt. In our arsenals they are made even lighter, their average being 13 cwt. 2 qrs. 14 lbs. Being rated with what are called "Park carriages," it is necessary they should conform as nearly as may be practicable with others of their class, and be drawn by the number of horses, &c. usually employed for light machines.

FORGE for red-hot balls, is a place where the balls are made red-hot before they are fired off: it is constructed about five or six feet below the surface of the ground, of strong brick-work, and an iron grate, upon which the balls are laid with a large fire under them.

Forth and Clyde Canal

FORTH and *Clyde canal*, is a navigable cut, which, connecting the rivers Forth and Clyde, forms a junction between the German ocean and the Irish sea. The utility of conjoining large rivers, for the purpose of extending their navigation, must be obvious to every reflecting mind, and in no instance did the geographical features of the country, and the circumstances which imperiously called for the execution of such a work, appear more striking than in this. The two rivers appeared to look with wishful eyes towards each other, and a natural passage presented itself through the mountains for conducting the union canal. Previous to this being made, the trade of this possessed no channel with the other side of the island, but by immense maritime distance round the Land's End; or by the less circuitous route, but dangerous passage of Pentland frith. Such an idea was conceived so early as the reign of Charles II., and the scheme met with some consideration; but that was not an age for this kind of national improvement. It then lay dormant till the year 1723, when a survey was made of the line of country by Mr. Gordon; still the undertaking was declined by the consideration of the expence. It was again revived in 1762; and a survey made by a Mr. Mackell, and another by Mr. Smeaton in 1764. From these surveys the practicability of the plan was ascertained, but its eligibility was yet questioned on the ground of the estimated expence, eighty thousand pounds. In the mean while a smaller canal was projected to extend from Glasgow to the Forth; parliament, however, refused to sanction the scheme on account of the smallness of the scale. Mr. Smeaton was then called in again to make a survey and estimate for cutting a canal, of such a breadth and depth, as would admit coasting vessels to pass from sea to sea. A subscription was accordingly opened, a bill obtained for leave to execute the plan, and the whole being placed under the direction of the able engineer who surveyed the ground, the undertaking commenced on July 10, 1768. After expending 150,000*l.* and overcoming difficulties which seemed at first insurmountable, it was rendered navigable as far as Stockingfield, where a branch, called Monkland, extends to the collieries to the east of Glasgow. The subscription and an additional loan having been exhausted, the work was here stopped, and in this state it remained till the year 1784, when the company, having obtained 50,000*l.* by forfeited estates, and an act of parliament for varying the line, Mr. Robert Whitworth, being appointed engineer, began to prosecute with great vigour and effect the further execution of the original plan. On the 28th of July, 1790, this immense undertaking was com-

pleted, and the navigation opened from sea to sea. Thus, with the aid of the collateral branch, a communication is formed between the great emporium of the north, Glasgow, and both sides of the island. The whole length of the canal is thirty-five miles from the mouth of the river Carron, to Dulmoreburn-foot, on the banks of the Clyde; rising and falling 160 feet, by means of 39 locks. In its course it passes over rocks, through precipices, deep mosses, over quick-sands, and in places is guarded by banks twenty feet high; crosses two considerable rivers, the Kelvin, and Luggie, with numerous rivulets and streams, by 10 large, and 33 smaller aqueducts or water bridges. That over the former river is a grand object, consisting of several arches, the centre one of which is 90 feet, forming an arcade 420 in the span in length, and 65 feet high. Various roads also traverse the canal by the aid of 33 draw-bridges. The dimensions of it, though greatly contracted from the original design, are far superior to any work of the kind in South Britain. The English canals are in general from three to five feet deep; from 20 to 30 feet wide; and the lock gates from ten to twelve feet; sufficiently capacious however to answer the purposes of inland carriage, from one town to another, for which they were exclusively designed. The following particulars will enable the reader to institute a comparison.

	Feet.
The medium width of the surface	- 56
Do. of the bottom	- 27
Depth on the average from sea to sea	8
The fall of each of the 39 locks	8
The breadth of each lock	20
The length of do. between the gates	74

The contrivance for supplying the canal with water was alone a difficult and arduous undertaking. No less than six reservoirs were found expedient; one near Kylesith covers a surface of 50 acres of land; another consists of 70; and the whole occupy about 409, containing by measurement 12,679 lockfulls of water. The expence of the whole concerned amounted to 300,000*l.* The toll for the whole line is 5*s.* 10*d.* per ton; against this is to be placed safety, time gained in passing from coast to coast; and the difference in insurance, that usually in time of war being in coasting it from 1*5*l. to 20*l.*; and by the canal, 5*l.* Phillips's General History of Inland Navigation, and Sinclair's General Statistical Account of Scotland.

Foundry

FOUNDERY, or **FOUNDRY**, the art of melting and casting all sorts of metals; particularly brass, iron, bell-metal, &c. The word is also used for a place, or work-house, furnished with furnaces, or forges for this purpose. **A foundry**, in the iron manufacture, is almost always connected with the blast furnace where the metal is smelted from the ore; from this circumstance we so frequently find the smelting furnace and its appendages termed a foundry, though in reality the word should be confined to the building for casting up the metal manufactured at the former; it is there termed the casting-house, (see the article **BLAST furnace**.) The casting-house, or foundry, is situated on one of the sides of the furnace, the surface of its ground about two feet below the level of the bottom of the hearth of the furnace. The floor of the foundry should be about ten feet deep, with the loamy sand, as mentioned in the article **CASTING**, of which the moulds are formed; this is for the convenience of burying large moulds beneath the surface, so that the metal may be conveyed into them by small channels or foughs hollowed out in the sand. A most important circumstance to be attended to is, that the foundry is well drained of water, as any dampness in moulds would produce the fatal explosions by the sudden expansion of the steam. When the hot metal is introduced into a wet mould, many serious accidents have arisen from a want of attention to this very necessary circumstance; in such a case, the moulds are burst asunder, the ground torn up, and the fluid metal thrown in every direction amongst the workmen, occasioning as much damage from its projectile force, as from its great heat, to those on whom it falls. Every foundry is furnished with a crane, or sometimes two, placed so as to command the whole for the convenience of taking up and removing heavy pieces of casting from any part of the place. At Butterby iron works, Derbyshire, we noticed an excellent crane for a foundry; the pulley from which the goods are suspended is not fixed to the end of the gib, but

slid upon it by means of a rack moved by a winch, which can be turned with ease by the workman, so as to give the crane any range within its reach; and it can take up weights as well at six feet from the centre as at ten, which renders it a most useful implement in such a situation, where the crane is frequently used to lower down moulds upon one another in a perpendicular direction, as mentioned in the article **CASTING**.

The most complete foundries are provided with two or more air or reverberating furnaces, (see **FURNACE**;) in which the metal is melted occasionally, either when the metal contained in the blast furnace is not sufficient, or when the quality of the metal made there is not proper for casting, owing to its containing too much or too little carbon, and it requires mixing with better or worse metal to render it fit for the purpose.

They have also two or three cupolas, or small blast furnaces, to melt small quantities of metal, particularly when it is wanted in haste, as the reverberatories are much longer in filling their charge of metal, though it is in greater quantity; but the latter does not so well answer the purposes of the iron founder, because it would require so great a stock of flasks and implements to make moulds to receive a large quantity of metal; for this reason they seldom employ the reverberatory but for large articles which require the whole charge; smaller goods are cast from the cupolas.

In the foundry of a blast furnace, a pit is sunk at a convenient distance from the furnace, and the moulds for pipes, and other similar articles, are placed vertically in it, within reach of the crane: the metal is conveyed by gutters or foughs from the furnace, and a small iron trough, filled with sand, leads the fluid metal into each of the moulds; these are a considerable improvement on the old method of burying them in the sand, in the saving of labour and time; the flasks are made of cast iron for the purpose.

It has of late become a practice at our most extensive

FOUNDERY

founderies, to substitute sand for loam castings in many cases where a great number of articles of one kind are to be cast, so that the expence of the flasks is not an object of importance; where the articles are intricate, the sand is wetted so much to render it sufficiently adhesive, that it is necessary to dry the moulds to avoid the danger of an explosion: for this purpose large stoves are used, and carriages adapted, on which to convey a great number of moulds into the stove at once, and when sufficiently dry, which generally happens in about half an hour, they are withdrawn, and a new set placed on the carriage.

A foundery is generally provided with a boring-mill for forming the internal surface of the cylinders cast for steam-engines, &c. (see *CYLINDER boring*), and the same machinery turns large lathes, for turning heavy mill axes, pistons, rollers for sugar-mills, and laminating rollers; the same mill gives motion to all these, and also blows the cupolas, though at a blast-furnace these are supplied by a small pipe from the great blowing-engine for the furnace.

FOUNDERY of small works, or the manner of casting in sand.—The sand used by the founders, in casting brads, &c. is yellowish, and pretty soft; but, after it has been used, it becomes quite black, because of the charcoal-dust used in the moulds. Every time they would use this sand, they work and tew it, several times over, on a board about a foot square, placed over a kind of trunk, or box, into which it may fall from off the board. This tewing is performed with a roller, or cylinder, about two feet long, and two inches in diameter; and a kind of knife, made of the blade of a sword: with these two instruments they alternately roll and cut the sand; and, at length, turn it down into the box or trough underneath.

Then, taking a wooden board, or table, of a length and breadth proportional to the quantity of things to be cast; round this they put a frame or ledge; and thus make a sort of mould. This mould they fill with the sand before prepared, and moderately moistened: which done, they take wooden, or metalline models, or patterns of the things intended to be cast: apply them on the mould, and press them down in the sand, so as to leave their form indented; along the middle of the mould is laid half a little cylinder of brads, which is to be the master jet, or canal for running the metal; being so disposed, as to touch the ledge on one side, and only to reach to the last pattern on the other: from this are placed several lesser jets or branches, reaching to each pattern, whereby the metal is conveyed through the whole frame.

This first frame being thus finished, they turn it upside down, to take out the pattern from the sand; in order to which, they first loosen them a little all round, with a small cutting instrument.

After the same manner they proceed to work the counterpart, or other half of the mould, with the same patterns, in a frame exactly like the former; excepting that it has pins, which, entering holes corresponding thereto in the other, make, when the two are joined together, the two cavities of the pattern fall exactly on each other.

The frame, being thus moulded, is carried to the founder, or melter; who, after enlarging the principal jet, or canal, of the counter-part, with a kind of knife, adding the cross jets, or canals, to the several patterns in both, and sprinkling them over with mill-dust, sets them to dry in an oven.

When both parts of the mould are sufficiently dried, they join them together, by means of the pins; and to prevent their starting, or slipping aside, by the force of the metal, which is to come in flaming hot, through a hole

contrived at the master-jet, they lock them in a kind of presses, either with screws; or if the mould be too big for this, with wedges. The moulds, thus put in the presses, are ranged near the furnace, to be in readiness to receive the metal as it comes out of the crucible.

While the moulds are thus preparing, the metal is put in fusion in an earthen crucible, about ten inches high, and four in diameter.

The furnace wherein the fusion is made is much like the smith's forge; having, like that, a chimney, to carry off the smoke; a pair of bellows to blow up the fire; and a hearth where the fire is made, and the crucible placed. It is the use of this hearth, that chiefly distinguishes the furnace from the forge.

In the middle thereof is a square cavity, ten or twelve inches wide, which goes to the very bottom: it is divided into two, by an iron grate: the upper partition serves to hold the crucible, and the fuel, and the lower to receive the ashes.

When the fuel, which is to be of dry wood, is pretty well lighted, they put the crucible full of metal in the middle, and cover it with an earthen lid; and, to increase the force of the fire, besides blowing it up with the bellows, they lay a tile over part of the aperture or cavity of the furnace.

The metal first put in being brought to a fusion, they fill the crucible with pieces of brads beaten in a mortar; to put them in they make use of a kind of iron ladle, with a long shank at the end thereof, formed into a kind of hollow cylinder, out of which the piece is dropped.

Nothing now remains, but for the founder to take the crucible out of the fire, and carry it in a pair of iron tongs (whose feet are bent, the better to embrace the top of the crucible) to the mould; into which he pours the melted metal, through the hole answering to the master-jet of each mould.

Thus he goes successively, from one to another, till his crucible is emptied, or there is not matter enough left for another mould.

Then casting cold water on the moulds, they take the frames out of the presses, and the cast works out of the sand: which afterwards they work again, for another casting. Lastly, they cut off the jets, or casts, and sell or deliver the work to those who bespoke it, without any farther repairing. See **BRASS** and **CASTING**.

FOUNDERY of statues, great guns, and bells.—The art of casting statues in brads is very ancient; inasmuch that its origin was too remote and obscure even for the research of Pliny; an author admirably skilled at discovering the inventors of other arts.

All we can learn for certain is, that it was practised, in all its perfection, first among the Greeks; and afterwards among the Romans: and that the number of their statues consecrated to their gods and heroes surpassed all belief. See **STATUE**.

The single cities of Athens, Delphos, Rhodes, &c. had each three thousand statues; and Marcus Scaurus alone, though only ædile, adorned the circus with no less than three thousand statues of brads, for the time of the Circensian games. This taste for statues was finally carried to such a pitch, that it became a proverb, that in Rome the people of brads were not less numerous than the Roman people.

Among us, the casting of statues was but little known or practised before the seventeenth century.

As to the *casting of guns*, it is quite modern; and it were perhaps to be wished, we were as ignorant of it as the

ancients. All authors agree, that the first cannon were cast in the fourteenth century; though some affix the event to the year 1338, and others to 1380. See CANNON and GUNNERY.

The *casting of bells* is of a middle standing, between the other two. The use of bells is certainly very ancient in the western church; and the same were likewise once used in the church of the east. But, at present, F. Vanfleb assures us, in his second account of Egypt, he had found but one bell in all the eastern church, and that in a monastery in the Upper Egypt. See BELL.

The matter of these large works is rarely any simple metal, but commonly a mixture of several. We shall here give the process in the foundry of each.

Method of casting statues of figures. See BRONZE.

There are three things chiefly required in casting of statues, busts, basso-relievos, vases, and other works of sculpture: *viz.* the mould, the wax, and shell, or coat. The inner mould, or core (thus called from *cœur*, as being in the heart or middle of the statue), is a rude lumpish figure, to which is given the attitudes and contours of the statue intended; it is raised on an iron grate, strong enough to sustain it; and is strengthened within by several bars, or ribs of iron.

It may be made at the discretion of the workmen; of potters' clay, mixed up with horse-dung and hair; or of plaster of Paris, mixed with fine brick-dust.

The use of the core in statues is to support the wax and shell, to lessen the weight, and to save metal. In bells it takes up all the inside, and preserves the space vacant where the clapper is hung. In great guns it forms the whole chase, from the mouth to the breech: and, in mortars, the chase and chamber. The iron bars and the core are taken out of the brass figure, through an aperture left in it, which is afterwards folded up: but it is necessary to leave some of the iron bars of the core that contribute to the steadiness of the projecting parts, within the brass figure.

The wax is a representation of the intended statue. If it be a piece of sculpture, the wax must be all of the sculptor's own hand, who usually fashions it on the core itself; though it may be wrought separately in cavities, moulded, or formed, on a model, and afterwards disposed and arranged on the ribs of iron over the grate, as before, filling the vacant space in the middle with liquid plaster and brick-dust; by which means the inner mould, or core, is formed in proportion as the sculptor carries on the wax.

When the wax (which is to be of the intended thickness of the metal) is finished, they fix little waxen tubes perpendicularly to it, from top to bottom; to serve, both as jets, for the conveyance of the metal to all parts of the work: and as vent holes, to give passage to the air, which would, otherwise, occasion great disorder, when the hot metal came to encompass it. By the weight of the wax used herein, is that of the metal adjusted; ten pounds of this last being the proportion to one pound of the former. The work brought thus far, wants nothing but to be covered with its shell; which is a kind of coat, or crust, laid over the wax: and which, being of a soft matter, and even, at first, liquid, easily takes and preserves the impression of every part thereof; which it afterwards communicates to the metal, upon its taking the place of the wax, between the shell and the core. The matter of this outer mould, or shell, is varied according as different layers, or strata are applied. The first is a composition of clay, and old white crucibles, well ground and sifted, and

mixed up with water, to the consistence of a colour fit for painting: accordingly, they apply it with a pencil, laying it seven or eight times over, letting it dry between the intervals. For the second impression, they add hories' dung, and natural earth to the former composition. The third impression is only hories' dung and earth. Lastly, the shell is finished by laying on several more impressions of this last matter, made very thick with the hand.

The shell, thus finished, is secured and strengthened by several bands, or girts of iron, wound round it at half a foot's distance from one another, and fastened at bottom to the grate under the statue; and at the top to a circle of iron, where they all terminate.

Here it must be observed, that if the statue be so big, that it would not be easy to move the moulds, when thus provided, it must be wrought on the spot where it is to be cast.

This is performed two ways; in the first, a square hole is dug under-ground, much bigger than the mould to be made therein, and its insides lined with walls of freestone, or brick. At the bottom is made a hole, of the same materials, with a kind of furnace, having its aperture outwards: in this is a fire to be lighted, to dry the mould; and afterwards, to melt the wax. Over this furnace is placed the grate; and on this the mould, &c. framed as before explained. Lastly, at one of the edges of the square pit is made another large furnace, to melt the metal, as hereafter mentioned.

In the other way, it is sufficient to work the mould above-ground: but with the same precaution of a furnace, and grate, underneath: when finished, four walls are to be run up round it: and, by the side thereof, a massive made, for a melting furnace. For the rest, the method is the same in both. The mould being finished, and inclosed between four walls, whether under-ground, or above it, a moderate fire is lighted in the furnace under it, and the hole covered with planks, that the wax may melt gently down, and run out at pipes contrived for the purpose, at the foot of the mould; which are afterwards very exactly closed with earth, as soon as all the wax is carried off.

This done, the hole is filled up with bricks thrown in at random, and the fire in the furnace is augmented till such time as both the bricks and the mould become red-hot; which ordinarily happens in twenty-four hours. Then, the fire being extinguished, and every thing cold again, they take out the bricks, and fill up their place with earth, moistened, and a little beaten, to the top of the mould, in order to make it the more firm and steady.

Things being in this condition, there remains nothing but to melt the metal, and run it into the mould; this is the office of the furnace above, which is made in manner of an oven, with three apertures; one to put in the wood; another for a vent; and a third to run the metal out at. From this last aperture, which is kept very close whilst the metal is in fusion, a little tube or canal is laid, whereby the melted metal is conveyed into a large earthen basin over the mould; into the bottom of which all the big branches of the jets, or casts, which are to carry the metal into all the parts of the mould, are inserted.

It must be added, that these jets are all terminated, or stopped with a kind of plugs, which are kept close, that upon opening the furnace the brass, which gushes out like a torrent of fire, may not enter any of them till the basin be full enough of matter to run into them all at once; upon which occasion they pull out the plugs, which are long iron rods, with a head at one end, capable of filling the whole diameter of each tube. The hole of the furnace

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is opened with a long piece of iron, fitted at the end of a pole; and the mould is then filled in an instant. The work is now finished, at least so much as belongs to the casting, the rest being the sculptor's or carver's business; who, taking the figure out of the mould and earth with which it is encompassed, saws off the jets, wherewith it appears covered over; and repairs it, with instruments proper to his art; as chisels, gravers, punchcons, &c.

The manner of casting bells.—What has been hitherto shewn of the casting of statues, holds, in proportion, of the casting of bells; that which is particular in these latter is as follows: first, then, the metal is different; there being no tin in the metal of statues, but no less than a fifth part of tin in that of bells. Secondly, the dimensions of the core, and the wax of bells, especially if it be a ring of several bells that is to be cast, are not left to chance, or the caprice of the workman; but must be measured, on a kind of scale, or diapason; which gives the height, aperture, and thickness, necessary for the several tones required.

It need not be added, that it is on the wax that the several mouldings and other ornaments, and inscriptions, to be represented in relieve, on the outside of the bell, are formed. The clapper, or tongue, is not properly a part of the bell, but is furnished from other hands. In Europe, it is usually of iron, with a large knob at the extreme; and is suspended in the middle of the bell. In China, it is only a huge wooden mallet, struck by force of arm against the bell; whence they can have but little of that consonancy, so much admired in some of our rings of bells. The Chinese have an extraordinary way of increasing the sound of their bells; *viz.* by leaving a hole under the caisson; which our bell-founders would reckon a defect.

The proportions of our bells differ very much from those of the Chinese. In our's, the modern proportions are, to make the diameter fifteen times the thickness of the brim, and the height twelve times. The parts of a bell are, 1. The sounding bow, terminated by an inferior circle, which grows thinner and thinner. 2. The brim or that part of a bell whereon the clapper strikes, and which is thicker than the rest. 3. The outward flinking of the middle of the bell, or the point under which it grows wider to the brim. 4. The waist or furniture, and the part that grows wider and thicker quite to the brim. 5. The upper vase, or that part which is above the waist. 6. The pallet which supports the staple of the clapper within. 7. The bent and hollowed branches of metal uniting with the caissons, to receive the iron keys, whereby the bell is hung up to the beam which is its support and counterpoise, when rung out. The business of bell-foundry is reducible to three particulars. 1. The proportion of a bell. 2. The forming of the mould. And, 3. The melting of the metal. There are two kinds of proportions, *viz.* the simple and the relative; the former are those proportions only that are between the several parts of a bell to render it sonorous; the relative proportions establish a requisite harmony between several bells. The method of forming the profile of a bell, previously to its being cast, in which the proportion of the several parts may be seen, is as follows: the thickness of the brim, C I (see *Plate XV. Miscellan. fig. 1.*) is the foundation of every other measure, and is divided into three equal parts. First, draw the line H D, which represents the diameter of the bell; bisect it in F and erect the perpendicular F f; let D F and H F be also bisected in E and G, and two other perpendiculars, E e, G g, be erected at E and G: G E will be the diameter of the top or upper vase, *i. e.* the diameter of the top will be half that of the bell; and it will, therefore, be the diameter of the bell which will found an oc-

tave to the other. Divide the diameter of the bell or the line H D into fifteen equal parts, and one of these will give C I the thickness of the brim; divide again each of these fifteen equal parts into three other equal parts, and then form a scale. From this scale take twelve of the larger divisions, or $\frac{2}{3}$ of the whole scale in the compass, and letting one leg in D describe an arc to cut the line E e in N, draw N D, and divide this line into twelve equal parts; at the point I erect the perpendicular I C = 10, and C I will be the thickness of the brim = $\frac{1}{15}$ of the diameter: draw the line C D: bisect D N and at the point of bisection G erect the perpendicular G K = $\frac{1}{15}$ of the larger divisions on the scale. With an opening of the compass equal to twice the length of the scale or thirty brims, setting one leg in N, describe an arc of a circle, and with the same leg in K and the same opening describe another arc to intersect the former: on this point of intersection, as a centre, and with a radius equal to thirty brims, describe the arc N K; in G K produced take K B = $\frac{1}{3}$ of the larger measure of the scale or $\frac{2}{3}$ of the brim, and on the same centre with the radius 30 brims describe an arc A B parallel to N K. For the arc B C, take twelve divisions of the scale or twelve brims in the compass, find a centre, and from that centre, with this opening, describe the arc B C, in the same manner as N K or A B was described. There are various ways of describing the arc K p; some describe it on a centre at the distance of nine brims from the points p and K; others, as it is done in the figure, on a centre at the distance only of seven brims from those points. But it is necessary first to find the point p, and to determine the rounding of the bell p I. For this purpose, on the point C as a centre and with the radius C I describe the arc I p n; bisect the part I, 2 of the line D n, and erecting the perpendicular p m, this perpendicular will cut the arc I p n in m, which terminates the rounding I p. Some founders make the bendings K a third of a brim lower than the middle of the line D N; others make the part C I D more acute, and instead of making C I perpendicular to D N at I, draw it $\frac{1}{3}$ th of a brim higher, making it still equal to one brim; so that the line I D is longer than the brim C I. In order to trace out the top-part N a, take in the compass eight divisions of the scale or eight brims, and on the points N and D, as centres, describe arcs to intersect each other in 8; on this point 8, with a radius of eight brims, describe the arc N b; this arc will be the exterior curve of the top or crown; on the same point 8, as a centre and with a radius equal to 7 brims, describe the arc A c, and this will be the interior curve of the crown, and its whole thickness will be one-third of the brim. As the point 8 does not fall in the axis of the bell, a centre M may be found in the axis by describing, with the interval of eight brims on the centres D and H, arcs which will intersect in M; and this point may be made the centre of the inner and outer curves of the crown, as before. The thickness of the cap which strengthens the crown at Q is about one-third of the thickness of the brim; and the hollow branches or ears about one-sixth of the diameter of the bell. The height of the bell is in proportion to its diameter as twelve to fifteen, or in the proportion of the fundamental sound to its third major; whence it follows that the sound of a bell is principally composed of the sound of its extremity or brim, as a fundamental, of the sound of the crown which is an octave to it, and of that of the height which is a third. *Encyclopædie, Art. CLOCHE. See BELL.*

The particulars necessary for making the mould of a bell are, 1. The earth: the most cohesive is the best; it must be well ground and sifted, to prevent any chinks. 2. Brick-stone; which must be used for the mine, mould, or core,

and for the furnace. 3. Horse dung, hair, and hemp, mixed with the earth, to render the cement more binding. 4. The wax for inscriptions, coats of arms, &c. 5. The tallow equally mixed with the wax, in order to put a slight layer of it upon the outer mould, before any letters are applied to it. 6. The coals to dry the mould.

For making the mould, they have a scaffold consisting of four boards, ranged upon tressels. Upon this they carry the earth, grossly diluted, to mix it with horse-dung, beating the whole with a large spatula.

The compasses of construction are the chief instrument for making the mould, which consist of two different legs, joined by a third piece. And last of all, the founders' shelves, on which are the engravings of the letters, carriages, coats of arms, &c.

They first dig a hole, of a sufficient depth to contain the mould of the bell, together with the case, or cannon, under ground; and about six inches lower than the terre-plein, where the work is performed. The hole must be wide enough for a free passage between the mould and walls of the hole; or between one mould and another, when several bells are to be cast. At the centre of the hole is a stake erected, that is strongly fastened in the ground. This supports an iron-peg, on which the pivot of the second branch of the compasses turns. The stake is encompassed with a solid brick-work, perfectly round, about half a foot high, and of the proposed bell's diameter. Thus they call a mill-stone. The parts of the mould are the core, the model of the bell, and the shell. When the outer surface of the core is formed, they begin to raise the core, which is made of bricks that are laid in courses of equal height upon a layer of plain earth. At the laying of each brick, they bring near it the branch of the compasses, on which the curve of the core is shaped, so as that there may remain between it and the curve the distance of a line, to be afterwards filled up with layers of cement. The work is continued to the top, only leaving an opening for the coals to bake the core. This work is covered with a layer of cement made of earth and horse-dung, on which they move the compasses of construction, to make it of an even smoothness every where.

The first layer being finished, they put the fire to the core, by filling it half with coals, through an opening that is kept shut, during the baking, with a cake of earth, that has been separately baked. The first fire consumes the stake, and the fire is left in the core half, or, sometimes, a whole day: the first layer being thoroughly dry, they cover it with a second, third, and fourth; each being smoothed by the board of the compasses, and thoroughly dried before they proceed to another.

The core being completed, they take the compasses to pieces, with intent to cut off the thickness of the model, and the compasses are immediately put in their place, to begin a second piece of the mould. It consists of a mixture of earth and hair, applied with the hand on the core, in several cakes that close together. This work is finished by several layers of a thinner cement of the same matter, smoothed by the compasses, and thoroughly dried, before another is laid on. The last layer of the model is a mixture of wax and grease spread over the whole. After which are applied the inscriptions, coats of arms, &c. besmeared with a pencil dipped in a vessel of wax on a chaffing-dish: this is done for every letter. Before the shell is begun, the compasses are taken to pieces, to cut off all the wood that fills the place of the thickness to be given to the shell.

The first layer is the same earth with the rest, sifted very fine; whilst it is tempering in water, it is mixed with cow's

hair, to make it cohere. The whole being a thin cullis, is gently poured on the model, that sinks exactly all the sinuities of the figures, &c. and this is repeated till the whole is two lines thick over the model. When this layer is thoroughly dried, they cover it with a second of the same matter, but something thicker: when this second layer becomes of some consistence, they apply the compasses again, and light a fire in the core, so as to melt off the wax of the inscriptions, &c.

After this, they go on with other layers of the shell, by means of the compasses. Here they add to the cow's hair a quantity of hemp, spread upon the layers, and afterwards smoothed by the board of the compasses. The thickness of the shell comes to four or five inches lower than the mill-stone before observed, and surrounds it quite close, which prevents the extravasation of the metal. The wax should be taken out before the melting of the metal.

The ear of the bell requires a separate work, which is done during the drying of the several incrustations of the cement. It has seven rings, the seventh is called the bridge, and unites the others, being a perpendicular support to strengthen the curves. It has an aperture at the top, to admit a large iron peg, bent at the bottom; and this is introduced into two holes in the beam, fastened with two strong iron keys. There are models made of the rings, with masses of beaten earth, that are dried in the fire, in order to have the hollow of them. These rings are gently pressed upon a layer of earth and cow's hair, one-half of its depth; and then taken out without breaking the mould. This operation is repeated twelve times for twelve half-moulds, that two and two united may make the hollows of the six rings: the same they do for the hollow of the bridge, and bake them all, to unite them together.

Upon the open place left for the coals to be put in, are placed the rings that constitute the ear. They first put into this open place the iron ring to support the clapper of the bell; then they make a round cake of clay, to fill up the diameter of the thickness of the core. This cake, after baking, is clipped upon the opening, and soldered with a thin mortar spread over it, which binds the cover close to the core.

The hollow of the model is filled with an earth, sufficiently moist, to fix on the place, which is strewed, at several times, upon the cover of the core; and they beat it gently with a pebble to a proper height; and a workman smooths the earth at top with a wooden trowel dipped in water.

Upon this cover, to be taken off afterwards, they assemble the hollows of the rings. When every thing is in its proper place, they strengthen the outside of the hollows with mortar, in order to bind them with the bridge, and keep them steady at the bottom, by means of a cake of the same mortar which fills up the whole aperture of the shell. This they let dry, that it may be removed without breaking. To make room for the metal they pull off the hollows of the rings, through which the metal is to pass, before it enters into the vacuity of the mould. The shell being unloaded of its ear, they range under the mill-stone five or six pieces of wood, about two feet long, and thick enough to reach almost the lower part of the shell: between these and the mould they drive in wooden wedges with a mallet, to shake the shell of the model whereon it rests, so as to be pulled up, and got out of the pit.

When this and the wax are removed, they break the model and layer of earth, through which the metal must run, from the hollow of the rings, between the bell and the core.

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They smoke the inside of the shell, by burning straw under it, that helps to smooth the surface of the bell. Then they put the shell in the place, so as to leave the same interval between that and the core; and before the hollows of the rings or the cap are put on again, they add two vents, that are united to the rings, and to each other, by a mass of baked cement. After which they put on this mass of the cap, the rings, and vents, over the shell, and folder it with thin cement, which is dried gradually by covering it with burning coals. Then they fill up the pit with earth, beating it strongly all the time, round the mould.

The furnace has a place for the fire, and another for the metal. The fire-place has a large chimney, with a spacious ash-hole: the furnace which contains the metal is vaulted, whose bottom is made of earth, rammed down; the rest is built with brick. It has four apertures; the first, through which the flame reverberates; the second is closed with a stopple, that is opened for the metal to run; the others are to separate the dross, or scoria, of the metal by wooden rakes; through these last apertures passes the thick smoke. The ground of the furnace is built sloping, for the metal to run down. See Dict. Commerc. Eng. edit. art. FOUNDERY.

FOUNDRY. *Manner of casting great guns, or pieces of artillery.*—The casting of cannons, mortars, and other pieces of artillery, is performed much like that of statues and bells; especially as to what regards the wax, shell, and furnaces.

All pieces of artillery are now cast solid, and bored afterwards, by means of a machine invented at Strasburgh, (see *Boring of CANNON*), and much improved by Mr. Verbruggen, head founder at Woolwich. The gun to be bored was at first placed in a perpendicular position; but the machines used for this purpose have lately been made to bore horizontally, and much more exactly than those that bore in a vertical situation. Whilst the inside is bored, the outside is turned and polished at the same time.

As to the metal, it is somewhat different from both; as having a mixture of tin, which is not in that of statues; and only having half the quantity of tin that is in bells, *i. e.* at the rate of ten pound of tin to an hundred of copper. The respective quantities of different metals that should enter into the composition for brass cannon is not absolutely decided; the most common proportions of the ingredients are the following: *viz.* to 240lb. of metal fit for casting, they put 68lb. of copper, 25lb. of brass, and 12lb. of tin. To 4200lb. of metal fit for casting, the Germans put 368; $\frac{1}{4}$ lb. of copper, 20; $\frac{1}{4}$ lb. of brass, and 307; $\frac{3}{4}$ lb. of tin. Others, again, use 100lb. of copper, 6lb. of brass, and 9lb. of tin; and lastly, others make use of 100lb. of copper, 10lb. of brass, and 15lb. of tin. See *CANNON*.

A cannon is always shaped a little conical, being thickest of metal at the breech, where the greatest effort of the gunpowder is made, and diminishing thence to the muzzle; so that if the mouth be two inches thick of metal, the breech is six. See *CANNON*.

Its length is measured in calibers, *i. e.* in diameters of the muzzle. Six inches at the muzzle require twenty calibers, or ten feet in length; there is always about the sixth of an inch allowed play for the ball. For the parts, and their respective proportions of different sorts of guns, see *CANNON* and *GUN*. The method of casting iron cannon differs very little from that of brass.

FOUNDRY. *Letter, or the method of casting printing Letters.*—The invention of printing letters we shall speak of under *PRINTING* and *LETTER*.

Their difference, kind, &c. have already been explained under the articles *CHARACTER*, &c.

In the business of cutting, casting, &c. letters for printing, the letter-cutter must be provided with a vice, hand-vice, hammers and files of all sorts for watch-makers' use; as also gravers and sculptors of all sorts, and an oil-stone, &c. suitable and sizeable to the several letters to be cut: a flat gauge made of box to hold a rod of steel, or the body of a mould, &c. exactly perpendicular to the flat of the using-file: a sliding gauge, whose use is to measure and set off distances between the shoulder and the tooth, and to mark it off from the end, or from the edge of the work; a face-gauge, which is a square notch cut with a file into the edge of a thin plate of steel, iron, or brass, of the thickness of a piece of common tin, whose use is to proportion the face of each sort of letter, *viz.* long letters, ascending letters, and short letters. So there must be three gauges, and the gauge for the long letters is the length of the whole body supposed to be divided into forty-two equal parts. The gauge for the ascending letters, Roman and Italic, are $\frac{5}{7}$, or 30 parts of 42, and 33 parts for the English face. The gauge for the short letters is $\frac{2}{3}$ or 18 parts of 42 of the whole body for the Roman and Italic, and 22 parts for the English face.

The Italic and other standing gauges are to measure the scope of the Italic stems, by applying the top and bottom of the gauge to the top and bottom lines of the letters, and the other side of the gauge to the stem; for when the letter complies with these three sides of the gauge, that letter has its true shape.

The next care of the letter-cutter is to prepare good steel punches, well-tempered, and quite free from all veins of iron; on the face of which he draws or marks the exact shape of the letter, with pen and ink, if the letter be large; or with a smooth blunted point of a needle, if it be small; and then with sizeable and proper shaped and pointed gravers and sculptors, digs or sculps out the steel between the strokes or marks he made on the face of the punch, and leaves the marks standing on the face. Having well shaped the inside strokes of his letter, he deepens the hollows with the same tools: for if a letter be not deep in proportion to its width, it will, when used at press, print black, and be good for nothing. This work is generally regulated by the depth of the counter-punch. Then he works the outside with proper files till it be fit for the matrice.

But before we proceed to the sinking and justifying of the matrices, we must provide a mould to justify them by, of which you have a draught in *Plate XV. Miscellany, figs. 2, 3*.

Every mould is composed of an upper and an under part. The under part is delineated in *fig. 2*. The upper part is marked *fig. 3*, and is in all respects made like the under part, excepting the stool behind, and the bow, or spring, also behind; and excepting a small roundish wire between the body and carriage, near the break where the under part hath a small rounding groove made in the body. This wire, or rather half-wire, in the upper part, makes the nick in the shank of the letter, when part of it is received into the groove in the under part. These two parts are so exactly fitted and gauged into one another (*viz.* the male gauge, marked *c* in *fig. 3*, into the female marked *g* in *fig. 2*.) that when the upper part of the mould is properly placed on, and in the under part of the mould, both together, make the entire mould, and may be slid backwards for use so far, till the edge of either of the bodies on the middle of either carriage comes just to the edge of the female gauges, cut in each carriage: and they may be slid for-

walks so far, till the bodies on either carriage touch each other: and the sliding of these two parts of the mould backwards makes the flank of the letter thicker, because the bodies in each part stand wider asunder, and the sliding them forwards makes the flank of the letter thinner, because the bodies on each part of the mould stand closer together.

The parts of the mould are as follow: viz.

- a The carriage.
- b The body.
- c The male gauge.
- d e The mouth-piece.
- f i The register.
- g The female gauge.
- h The hag.
- a a a The bottom plate.
- b b b The wood, on which the bottom plate lies.
- c c c The mouth.
- d d The throat.
- e d d The pallet.
- f The nick.
- g g The stool.
- b b The spring or bow.

Then the mould must be justified: and first the foundry justifies the body, by casting about twenty proofs or samples of letters, which are set in a composing stick, with all their nicks towards the right hand; and then by comparing these with the pattern letters, set up in the same manner, he finds the exact measure of the body to be cast. He also tries if the two sides of the body are parallel, or that the body be no bigger at the head than at the foot; by taking half the number of his proofs, and turning them with their heads to the feet of the other half; and if then the heads and the feet be found exactly even upon each other, and neither to drive out nor get in, the two sides may be pronounced parallel. He farther tries whether the two sides of the thickness of the letter be parallel by first setting his proofs in the composing stick with their nicks upwards; and then turning one-half with their heads to the feet of the other half: and if the heads and feet lie exactly upon each other, and neither drive out nor get in, the two sides of the thickness are parallel.

The mould thus justified: the next business is to prepare the matrices. A matrix is a piece of brass or copper of about an inch and a half long, and of a thickness in proportion to the size of the letter it is to contain. In this metal is sunk the face of the letter intended to be cast, by striking the letter punch about the depth of an n. After this the sides and face of the matrix must be justified and cleared, with files, of all bunnings made by sinking the punch.

Every thing thus prepared, it is brought to the furnace, which is built of brick upright, with four square sides, and a stone on the top, in which stone is a wide round hole for the pan to stand in. A foundry of any consequence has several of these furnaces in it.

As to the metal of which the types are to be cast, this, in extensive foundries, is always prepared in large quantities; but cast into small bars of about twenty pounds weight to be delivered out to the workmen as occasion requires. In the letter foundry which has been long carried on with reputation, under the direction of Dr. Alexander Wilson, and sons, at Glasgow, we are informed, that a stock of metal is made up at two different times of the year, sufficient to serve the casters at the furnace for six months each time. For this purpose a

large furnace is built under a shade, furnished with a wheel vent, in order the more equally to heat the sides of a strong pot of cast iron, which holds, when full, fifteen hundred weight of the metal. The fire being kindled below, the bars of lead are let softly down into the pot, and their fusion promoted by throwing in some pitch and tallow, which soon inflame. An outer chimney, which is built so as to project about a foot over the farthest lip of the pot, catches hold of the flame by a strong draught, and makes it act very powerful in melting lead; whilst it serves at the same time to convey away all the fumes, &c. from the workmen, to whom this laborious part of the business is committed. When the lead is thoroughly melted, a due proportion of the regulus of antimony and other ingredients are put in, and some more tallow is inflamed, to make the whole incorporate sooner. The workmen now having mixed the contents of the pot very thoroughly, by stirring long with a large iron ladle, next proceed to draw the metal off into the small troughs of cast iron which are ranged, to the number of fourscore, upon a level platform, faced with stone, built towards the right hand. In the course of a day fifteen hundred weight of metal can be easily prepared in this manner; and the operation is continued for as many days as are necessary to prepare a stock of metal, of all the various degrees of hardness. After this the whole is disposed into presses, according to its quality, to be delivered out occasionally to the workmen.

The foundry must be now provided with a ladle, which differs nothing from other iron ladles, but in its size. And he is provided always with ladles of several sizes, which he uses according to the size of the letter he is to cast. Before the caster begins to cast, he must kindle his fire in the furnace to melt the metal in the pan. Therefore he takes the pan out of the hole in the stone, and there lays in coals and kindles them; and, when they are well kindled, he sets the pan in again and puts in metal into it to melt; if it be a small bodied letter he casts, or a thin letter of great bodies, his metal must be very hot; nay sometimes red-hot, to make the letter come. Then having chosen a ladle that will hold about so much as the letter and break is, he lays it at the stoking hole, where the flame bursts out, to heat. Then he ties a thin leather, cut with its narrow end against the face to the leather groove of the matrix, by whipping a brown thread twice about the leather-groove, and fastening the thread with a knot. Then he puts both halves of the mould together, and puts the matrix into the matrix-check, and places the foot of the matrix on the stool of the mould, and the broad end of the leather upon the wood of the upper half of the mould, but not tight up, lest it might hinder the foot of the matrix from sinking close down upon the stool in a train of work. Then laying a little rosin on the upper-wood of the mould, and having his casting-ladle hot, he with the boiling side of it melts the rosin; and, when it is yet melted, presses the broad end of the leather hard down on the wood, and so fastens it to the wood: all this is the preparation.

Now he comes to casting. Wherefore placing the under half of the mould in his left hand with the hook or hag forward, he clutches the ends of its wood between the lower part of the ball of his thumb and his three hind fingers; then he lays the upper half of the mould upon the under half, so that the male gauges may fall into the female gauges, and at the same time the foot of the matrix places itself upon the stool; and, clapping his left

FOUNDRY

and thumb strong over the upper half of the mould he nimbly catches hold of the bow or spring with his right hand fingers at the top of it, and his thumb under it, and places the point of it against the middle of the notch in the backside of the matrice, pressing it as well forwards towards the mould, as downwards, by the shoulder, of the notch close upon the stool, while at the same time with his hinder fingers, as aforesaid, he draws the under half of the mould towards the ball of his thumb, and thrusts by the ball of his thumb the upper part towards his fingers, that both the registers of the mould may press against both sides of the matrice, and his thumb and fingers press both halves of the mould close together.

Then he takes the handle of his ladle in his right hand, and with the boll of it gives a stroke, two or three, outwards upon the surface of the melted metal, to scum or clear it from the film or dust that may swim upon it; then takes up the ladle full of metal, and having his mould, as aforesaid, in his left hand, he a little twists the left side of his body from the furnace, and brings the great of his ladle (full of metal) to the mouth of the mould, and twists the upper part of his right hand towards him to turn the metal into it, while at the same moment of time he jilts the mould in his left hand forwards, to receive the metal with a strong shake (as it is called); not only into the bodies of the mould, but while the metal is yet hot running, swiftly and strongly, into the very face of the matrice, to receive its perfect form there, as well as in the flank.

Then he takes the upper half of the mould off the under half, by placing his right hand thumb on the end of the wood next his left hand thumb, and his two middle-fingers at the other end of the wood; and finding the letter and break lie in the under half of the mould, (as most commonly by reason of its weight it does,) he throws or tosses the letter, break and all, upon a sheet of waste paper laid for that purpose on the bench, just a little beyond his left hand, and is then ready to cast another letter as before; and also, the whole number that is to be cast with that matrice.

A workman will ordinarily cast about three thousand of these letters in a day.

When the casters at the furnace have got a sufficient number of types upon the tables, a set of boys come, and nimbly break away the jets from them: the jets are thrown into the pots, and the types are carried away in parcels to other boys, who pass them swiftly under their fingers, defended by leather, upon smooth flat stones, in order to polish their broad-sides. This is a very dextrous operation, and is a remarkable instance of what may be effected by the power of habit and long practice; for these boys, in turning up the other side of the type, do it so quickly by a mere touch of the fingers of the left hand, as not to require the least perceptible intermission in the motion of the right hand upon the stone. The types, thus finely smoothed and flattened on the broad-sides, are next carried to another set of boys, who sit at a square table, two on each side, and there are ranged up on long rulers, or sticks, fitted with a small projection, to hinder them from sliding off backwards. When these sticks are so filled, they are placed, two and two, upon a set of wooden pins fixed into the wall, near the dresser, sometimes to the amount of a hundred, in order to undergo the finishing operations. This workman, who is always the most expert and skilful in all the different branches carried on at the foundry, begins by taking one of these sticks, and, with a peculiar address, slides the whole column of types off upon the dressing-stick: this is made of

well-seasoned mahogany, and furnished with two end-pieces of steel, a little lower than the body of the types, one of which is moveable, so as to approach the other by means of a long screw-pin, inserted in the end of the stick. The types are put into this stick with their faces next to the back or projection; and after they are adjusted to one another so as to stand even when they are bound up, by screwing home the moveable end piece. It is here where the great and requisite accuracy of the moulds comes to be perceived; for in this case the whole column, so bound up, lies flat and true upon the stick, the two extreme types being quite parallel, and the whole has the appearance of one solid continuous plate of metal. The least inaccuracy in the exact parallelism of the individual type, when multiplied so many times, would render it impossible to bind them up in this manner, by disposing them to rise or spring from the stick by the smallest pressure from the screw. Now, when lying so conveniently with the narrow edges uppermost, which cannot possibly be smoothed in the manner before mentioned by the stones, the workman does this more effectually by scraping the surface of the column with a thick-edged but sharp razor, which at every stroke brings on a very fine smooth skin, like to polished silver; and thus he proceeds till in about half a minute he comes to the farther end of the stick. The other edges of the types are next turned upwards, and polished in the same manner. It is whilst the types thus lie in the dressing-stick that the operation of bearding or barbing is performed, which is effected by running a plane, faced with steel, along the shoulder of the body next to the face, which takes more or less off the corner, as occasion may require. Whilst in the dressing-stick they are also grooved, which is a very material operation. In order to understand this, it must be remembered, that when the types are first broken off from the jets, some superfluous metal always remains, which would make them bear very unequally against the paper whilst under the printing-press, and effectually mar the impression. That all these inequalities may, therefore, be taken away, and that the bearings of every type may be regulated by the shoulders imparted to them all alike from the mould, the workman or dresser proceeds in the following manner. The types being screwed up in the stick, as before mentioned, with the jet-end outermost, and projecting beyond the wood about one eighth of an inch, the stick is put into an open press, so as to present the jet-end uppermost, and then every thing is made fast by driving a long wedge, which bears upon a slip of wood, which lies close to the types the whole length: then a plough or plane is applied, which is so constructed as to embrace the projecting part of the types betwixt its long sides, which are made of polished iron. When the plane is thus applied, the steel cutter bearing upon that part between the shoulders of the types, where the inequalities lie, the dresser dextrously glides it along, and by this means strips off every irregular part that comes in the way, and so makes an uniform groove the whole length, and leaves the two shoulders standing; by which means every type becomes precisely like to another, as to the height against paper. The types being now finished, the stick is taken out of the press, and the whole column replaced upon the other stick; and after the whole are so dressed, he proceeds to pick out the bad letters, previously to putting them up into pages and papers. In doing this he takes the stick into his left hand, and turning the faces near to the light, he examines them carefully, and whenever an imperfect or damaged letter occurs, he nimbly plucks it out with a sharp bodkin, which he holds in the right hand for that purpose. Those letters which, from their form, project over the body

of the type, and which cannot on this account be rubbed on the stones, are scraped on the broad-sides with a knife or file, and some of the metal next the face pared away with a pen-knife, in order to allow the type to come close to any other. This operation is called kerning.

The excellence of printing types consists not only in the due performance of all the operations above described, but also in the hardness of the metal, form, and fine proportion of the character, and in the exact bearing and ranging of the letters in relation to one another.

FOUNDERY, Military. Under the several appropriate heads, we have furnished information regarding the several kinds of foundry necessary to the establishment of that variety of professions, wherein castings of different kinds, whether in metal, wax, plaster, &c. are desiderata: we now have to offer a few remarks on such as appertain more particularly to the supply of our arsenals.

The casting of cannon, shot, &c. was, until about half a century ago, considered an arduous undertaking; and so little were the fundamental principles of the art understood, that we are assured not one in three of the shells cast for the mortar service could be admitted into the stores. Such have been the improvements made, that thousands of articles, which used to be from necessity made of wrought iron, are now to be had from the foundries at less than one-fifth of their former prices; while the material itself has been so highly perfected, that instances have been known of cast-iron being sufficiently soft to bear the file, and sufficiently ductile to undergo the hammer. Such, indeed, could not be done but at considerable expence; nor does it appear that much good could result in general. With respect to military apparatus, it is found expedient to have the whole of our cannon, mortars, carroades, shot, shells, and garrison gun-carriages, cast at the several foundries established in the vicinity of coal and iron mines; whereby the work is done at comparatively a low expence, and the articles can be conveyed by water to the warren at Woolwich much under the prices at which they could be cast at the place, to which both the iron and the coals must be transported.

The French have, since the commencement of the revolution, shewn what may be effected in this branch of

military economy, by a people determined to overcome every difficulty, and to apply their resources, whether public or private, towards national purposes. It is a well ascertained fact, that in several of the departments of France, from which the trains of artillery, together with the several stores appertaining to them, had been withdrawn, the people supplied their national guards with field-pieces cast in small temporary foundries, where the furnaces were rarely equal to heating more than from twenty to thirty pounds of bell-metal, &c. of which the sacred edifices, & throughout the country had been stripped. By a due combination of the whole, very serviceable cannon, and especially howitzers, which seem to be a favourite species of artillery among the French, were thus supplied.

Though it must be admitted that a foundry suited to casting cannon, of any description, could not be attached to the ordnance department of armies serving out of the kingdom, we are inclined to hazard the opinion, that small laboratory furnaces, adequate to the casting of shot and grape, but especially of musket balls, might be annexed thereto. In some instances, when the stock of grape-shot has been expended, it has become necessary to make case-shot of musket balls, whereby the infantry have been very ill supplied with ammunition. If, in such instances, portable furnaces, and crucibles, together with proper moulds, have been at hand, (for the whole might be conveyed in a wagon, or perhaps in a cart,) abundance of reusable iron could have been formed into grape-shot; and there would have been no scarcity of musket ammunition.

Nor can we see any objection to the supply of proper materials for establishing foundries, suited to casting field-pieces, being shipped with extensive armaments proceeding on foreign service; since the space they would occupy must be far less than is required for that immense quantity of stores necessarily sent to places where no foundry exists. Hence tonnage, time, and treasure, are often lavishly expended. The casting of shot and shells, in such situations, would generally prove easy, and liberate many a transport from the conveyance of such dead-weight, as not only precludes the supply of other equally necessary stores, but, in many instances, sinks, or even causes, a total loss.

Fuel

FUEL, in *Philosophy*, the pabulum of fire, or whatever receives and retains fire, and is consumed, or rendered insensible thereby.

A great deal of nicety is required in choosing the proper fuel to raise and continue the several degrees of fire in chemical operations. Dr. Black divides fuels into five

classes; the first comprehends the fluid inflammable bodies; the second, peat or turf; the third, charcoal of wood; the fourth, pit-coal charred; and the fifth, wood, or pit-coal, in a crude state, and capable of yielding a copious and bright flame.

The fluid inflammables are considered as distinct from the solid, on this account, that they are capable of burning upon a wick, and become in this way the most manageable sources of heat; though, on account of their price, they are never employed for producing it in great quantities; and are only used when a gentle degree, or a small quantity of heat is sufficient. The species which belong to this class are alcohol and different oils.

The first of these, alcohol, when pure and free of water, is as convenient and manageable a fuel for producing moderate or gentle heats as can be desired. Its flame is perfectly clean, and free from any kind of soot; it can easily be made to burn slower or faster, and to produce less or more heat, by changing the size or number of the wicks upon which it burns; for as long as these are fed with spirit, in a proper manner, they continue to yield flame of precisely the same strength. The cotton, or other materials, of which the wick is composed, is not scorched or consumed in the least, because the spirit with which it is constantly soaked is incapable of becoming hotter than 174° Fahrenheit, which is considerably below the heat of boiling water. It is only the vapour that arises from it which is hotter, and this too only in its outer parts, that are most remote from the wick, and where only the combustion is going on, in consequence of communication and contact with the air. At the same time, as the alcohol is totally volatile, it does not leave any fixed matter which, by being accumulated on the wick, might render it foul and fill up its pores. The wick, therefore, continues to imbibe the spirit as freely, after some time, as it did at the first. These are the qualities of alcohol as a fuel. But these qualities belong only to a spirit that is very pure. If, on the contrary, it be weak, and contain water, the water, being less volatile, does not evaporate so fast from the wick as the more spirituous part; and the wick becomes, after some time, so much soaked with water that it does not imbibe the spirit properly. The flame becomes much weaker, or is altogether extinguished. When alcohol is used as a fuel, therefore, it ought to be made as strong, or free from water, as possible.

Oil, although fluid like spirit of wine, and capable of burning in a similar manner, is not so convenient in many respects. It is disposed to emit soot; and thus applying itself to the bottom of the vessel exposed to it, and, increasing in thickness, forms, by degrees, a soft and spongy medium, through which heat is not so freely and quickly transmitted. This was observed by Muschenbroeck in his experiments upon the expansions of metalline rods heated by lamps. It is true we can prevent this entirely, by using very small wicks, and increasing the number, if necessary, to produce the heat required. Or, we may employ one of those lamps, in which a stream of air is allowed to rise through the middle of the flame, or to pass over its surface with such velocity as to produce a more complete inflammation than ordinary. But we shall be as much embarrassed in another way, for the oils commonly used, being capable of assuming a heat greatly above that of boiling water, scorch and burn the wick, and change its texture, so that it does not imbibe the oil so fast as before. Some have attempted a remedy, by making the wick of incombustible materials, as asbestos, or wire; but still, as the oil does not totally evaporate, but leaves a small quantity of gross fixed

carbonaceous matter, this, constantly accumulating, clogs the wick to such a degree, that the oil cannot ascend, the flames become weaker, and, in some cases, are entirely extinguished. There is, however, a difference among the different oils in this respect; some being more totally volatile than others. But the best are troublesome in this way, and the only remedy is to change the wicks often, though we can hardly do this and be sure of keeping always an equal flame.

The second kind of fuel mentioned, peat, is so spongy that, compared with the more solid fuels, it is unfit to be employed for producing very strong heats. It is too bulky for this: we cannot put into a furnace, at a time, a quantity that corresponds with the quick consumption that must necessarily go on when the heat is violent. There is, no doubt, a great difference in this respect among different kinds of this fuel; but this is the general character of it. However, when we desire to produce and keep up, by means of cheap fuel, an extremely mild gentle heat, it can hardly use any thing better than peat. But it is best to have it previously charred, that is, scorched, or burnt to black coal. When prepared for use in that manner, it is capable of being made to burn more slowly and gently, or will bear, without being extinguished altogether, a great diminution of the quantity of air, with which it is supplied, than any other of the solid fuels. Dr. Boerhaave found it extremely convenient and manageable in his *Furnus Studii* forum.

The next fuel, in order, is the charcoal of wood. This is prepared by piling up billets of wood into a pyramidal heap, with several spiracles, or flues, formed through the pile. Chips and brushwood are put into those below, and the whole is so constructed that, when kindled, it kindles almost over the whole pile in a very short time. It would burst out into a blaze, and be quickly consumed to ashes, were it not covered all over with earth, or clay, beaten close, leaving openings at all the spiracles. These are carefully watched; and, whenever the white watery smoke is observed to be succeeded by thin blue, and transparent smoke, the whole is immediately stopped; this being the indication of all the watery vapour being gone, and the burning of the true coaly matter commencing. Thus is a pretty strong red heat raised through the whole mass, and all the volatile matters are dissipated by it, and nothing now remains but the charcoal. The holes being all stopped in succession, as this change of the smoke is observed, the fire goes out for want of air. The pile is now allowed to cool. This requires many days; for, charcoal being a very bad conductor of heat, the pile long remains red hot in the centre, and, if opened in this state, would instantly burn with fury.

Small quantities may be procured at any time, by burning wood in close vessels. Little pieces may be very finely prepared, at any time, by plunging the wood in lead melted and red hot.

This is the chief fuel used by the chemists abroad, and has many good properties. It kindles quickly, emits few watery or other vapours while burning, and when consumed leaves few ashes, and those very light. They are, therefore, easily blown away, so that the fire continues open, or pervious to the current of air which must pass through it to keep it burning. This sort of fuel, too, is capable of producing as intense a heat as can be obtained by any; but in those violent heats it is quickly consumed, and needs to be frequently supplied.

Fossil coals charred, called cinders, or coals, have, in many respects, the same properties as charcoal of wood; as kindling more readily in furnaces than when they are not charred, and not emitting watery, or other gross smoke,

while they burn. This sort of charcoal is even greatly superior to the other in some properties.

It is a much stronger fuel, or contains the combustible matter in greater quantity, or in a more condensed state. It is, therefore, consumed much more slowly on all occasions, and particularly when employed for producing intense melting heats. The only inconveniences that attend it are, that, as it consumes, it leaves much more ashes than the other, and these much heavier too, which are, therefore, liable to collect in such quantity as to obstruct the free passage of air through the fire; and further, that when the heat is very intense these ashes are disposed to melt or vitrify into a tenacious drossy substance, which clogs the grate, the sides of the furnace and the vessels. This last inconvenience is only troublesome, however, when the heat required is very intense. In ordinary heat the ashes do not melt, and though they are more copious and heavy than those of charcoal of wood, they seldom choke up the fire considerably, unless the bars of the grate be too close together.

This fuel, therefore, is preferable, in most cases, to the charcoal of wood, on account of its burning much longer, or giving much more heat before it is consumed. The heat produced, by equal quantities, by weight, of pit-coal, wood-charcoal and wood itself, are nearly in proportion of 5, 4, and 3. The reason why both these kinds of charcoal are preferred, on most occasions, in experimental chemistry, to the crude wood, or fossil coal from which they are produced, is, that the crude fuels are deprived, by charring, of a considerable quantity of water, and some other volatile principles, which are evaporated during the process of charring, in the form of footy smoke or flame. These volatile parts, while they remain in the fuel, make it unfit (or less fit) for many purposes in chemistry. For besides obstructing the vents with footy matter, they require much heat to evaporate them; and, therefore, the heat of the furnace, in which they are burnt, is much diminished and wasted by every addition of fresh fuel, until the fresh fuel is completely inflamed, and restores the heat to its former strength.

But these great and sudden variations of the heat of a furnace are quite inconvenient in most chemical processes. In the greater number of chemical operations, therefore, it is much more convenient to use charred fuel, than the same fuel in its natural state.

There are, at the same time, some kinds of fossil coal, which are exceptions to what has now been delivered in general. We meet with some of them that leave a smaller proportion of ashes than others, and the ashes of some are not so liable to melt in violent heats. There is one species too, such as the Kilkenny coal of Ireland, and which occurs likewise in some parts of this country, that does not contain any sensible quantity of water, or other such volatile principles. But this may be called a sort of native charcoal. It has the appearance of ordinary coal, but, when thrown into the fire, does not emit smoke or soot. It merely becomes red, gives a subtile blue flame, and consumes like charcoal; only it lasts surprizingly long, or continues to give heat for a very long time before it is totally consumed. But it cannot be made to burn so as to produce a gentle heat. If not in considerable quantity, and violently heated, it is soon extinguished.

In using this kind of fuel, it is proper to be on our guard against the dangerous nature of the burnt air, which arises from charcoal of all kinds. Charcoal burns without visible smoke. The air arising from it appears to the eye as pure and as clear as common air. Hence it is much used abroad

by those who are studious of neatness, and cleanliness in their apartments. But this very circumstance should make us more watchful against its effects, which may prove dangerous, in the highest degree, before we are aware of it. The air arising from common crude fuel is no doubt as bad, but the smoke renders it disagreeable before it becomes dangerous. The first sensation is a slight sense of weakness; the limbs seem to require a little attention, to prevent falling. A slight giddiness, accompanied by a distinct feeling of a flush, or glow in the face and neck. Soon after, the person becomes drowsy, would sit down, but commonly falls on the floor insensible of all about him, and breathes strong, snoring as in an apoplexy. If the person is alarmed in time, and escapes into the open air, he is commonly seized with a violent head-ach, which gradually abates.

But when the effect is completed, as above described, death very soon ensues, unless relief be obtained. There is usually a foaming at the mouth, a great flush or suffusion over the face and neck, and every indication of an oppression of the brain, by this accumulation of blood. The most successful treatment is to take off a quantity of blood immediately, and throw cold water on the head repeatedly. A strong stimulus, such as hartshorn, applied to the soles of the feet, has also a very good effect.

The fifth and last kind of fuel is wood, or fossil coals, in their crude state, which it is proper to distinguish from the charcoals of the same substances. The difference consists in their giving a copious and bright flame, when plenty of air is admitted to them, in consequence of which they must be considered as fuels very different from charcoal, and adapted to different purposes. See FLAME.

Flaming fuel cannot be managed like the charcoals. If little air be admitted, it gives no flame, but footy vapour, and a diminution of heat. And if much air be admitted to make those vapours break out into flame, the heat is too violent. These flaming fuels, however, have their particular uses, for which the others are far less proper. For it is a fact, that flame, when produced in great quantity, and made to burn violently, by mixing it with a proper quantity of fresh air, by driving it on the subject, and throwing it into whirls and eddies, which mix the air with every part of the hot vapour, gives a most intense heat. This proceeds from the vaporous nature of flame, and the perfect miscibility of it with the air.

As the immediate contact and action of air are necessary to the burning of every combustible body; so the air, when properly applied, acts, with far greater advantage on flame, than on the solid and fixed inflammable bodies: for when air is applied to these last, it can only act on their surface, or the particles of them that are outermost; whereas flame being a vapour or elastic fluid, the air, by proper contrivances, can be intimately mixed with it, and made to act on every part of it, external and internal, at the same time. This great power of flame, which is the consequence of this, does not appear when we try small quantities of it, and allow it to burn quietly, because the air is not intimately mixed with it, but acts only on the outside, and the quantity of burning matter in the surface of a small flame is too small to produce much effect.

But when flame is produced in large quantity, and is properly mixed and agitated with air, its power to heat bodies is immensely increased. It is therefore peculiarly proper for heating large quantities of matter to a violent degree especially if the contact of solid fuel with such matter is inconvenient. Flaming fuel is used for this reason in many operations performed on large quantities of metal, or metallic minerals, in the making of glass, and in the baking or

Burning of all kinds of earthen ware. The potter's kiln is a cylindrical cavity, filled from the bottom to the top with columns of wares; the only interstices are those that are left between the columns; and the flame, when produced in sufficient quantity, proves a torrent of liquid fire, constantly flowing up through the whole of the interstices, and heats the whole pile in an equal manner.

Flaming fuel is also proper in many works or manufactories, in which much fuel is consumed, as in breweries, distilleries, and the like. In such works, it is evidently worth while to contrive the furnaces so that heat may be obtained from the volatile parts of the fuel, as well as from the fixed; for when this is done, less fuel serves the purpose than would otherwise be necessary. But this is little attended to, or ill understood in many of those manufactories. It is not uncommon to see vast clouds of black smoke and vapour coming out of their vents. This happens in consequence of their throwing too large a quantity of crude fuel into the furnace at once. The heat is not sufficient to inflame it quickly, and the consequence is a great loss of heat. See **LABORATORY**.

It is a known truth, that fuel cannot consume by means of heat alone, without the admission of fresh air, and this is no way more clearly proved, than by this easy experiment. Let a strong cylinder of iron, hollow within, be fitted with a firm screw at each end; in the cavity of this cylinder enclose a long piece of charcoal, and then screw up both the ends fast, and place the whole in a strong fire; let it continue there for several hours; and when it is taken out and cooled, open it, and the piece of charcoal will be found still black, in its own form, and no way apparently altered or diminished.

It is plain from this, that the consumption of fuel depends upon the rarefaction, dislodgment, brisk agitation, and discharge of its inflammable vapour, by means of fresh air; and hence we have the reason of the known rule of extinguishing fires by smothering them.

It is provided by statute, that wood fuel shall not be felled under the assize. See **BILLET** and **FAGGOTS**.

Fuller's Earth

FULLERS' Earth, in *Mineralogy*, *Argilla Smeëtis*, Waller; *Talcum fullonum*, Wern.; *Talcum Smeëtis*, Linn.; *Fullonia communis*, Forst.; *Argille Smeëlite*, Haüy; *Terre à foulon*, Fr.; *Walker-Erde*, Germ.; *Walk-lera*, Swed.; a species of earth, which from the predominance of siliceous as a constituent part, (at least in the varieties analyzed by Bergmann and Klaproth,) should be referred to the siliceous genus, though Werner, guided by what he terms the characteristic component part, places it in the first division of his talc genus, together with bole, native talc earth, and écume de mer. Emmerling places it in his flint genus, in the same manner as all the varieties of common clay are transferred by him to that genus. It is fruitless to enter on any discussion with regard to the place a fossil is to occupy in a system, before all its relations, oryctognostical, chemical, and geological, are thoroughly understood; and this is more than at present can be said of fullers' earth, which, in common with other mineral substances, denominated from the particular uses to which they may be applied, is, both by collectors and writers, continually confounded with other substances, especially with varieties of common clay. Hence it is that we find so very contradictory descriptions of the characters of this earth. The following external characters are principally derived

from the varieties found in England, in Saxony, (particularly at Rosswein, at the foot of the Saxon Ertzgebirge) in Austria, Moravia, the Palatinate, Alsace, and Silesia. Many of those from other parts of Europe that we have had an opportunity of seeing in collections, appeared to partake too much of the nature of common clay, others of that of steatite, while others again exhibited characters belonging to varieties of marble.

Fullers' earth is generally of a greenish colour, more or less mixed with brown and grey, together with a portion of yellow, by which various shades of dirty olive green are produced; sometimes the yellow predominates, and a yellowish grey appears, passing over (in the genuine *Lemnian earth*, which, as we shall shew hereafter, cannot be separated from fullers' earth,) into whitish grey. It is also found of various shades of red; that of Silesia is tile red, sometimes sprinkled with white and green spots. Often several of the just mentioned colours are intimately, but mechanically, mixed; which, in some, can be observed only with the assistance of a magnifying glass. The brown colour, both uniform and in spots, is generally owing to an accidental admixture of iron ochre.

It has been found massive only, sometimes constituting whole fletz-litrate. Large masses, on being separated, generally disintegrate into smaller pieces, when exposed to the influence of the atmosphere.

Internally it is more or less dull; its fracture being earthy, generally of a fine grain: often it appears perfectly conchoidal, and even flaty; but commonly the fragments are indeterminate angular and blunt-edged, and in the latter case perfectly opaque: in the purest varieties the edges are sometimes translucent. When scratched with the nail of the finger, or cut with a knife, it becomes smooth and shining.

It is very soft, almost friable, and mild; feels more or less greasy, and scarcely adheres to the tongue. It does not soil. Specific gravity about 2.

Genuine fullers' earth does not effervesce with nitrous acid; nor are all varieties of it instantly reduced into powder by that acid. But small pieces put into water almost instantly crumble into conical heaps of minute, very soft particles, without producing a crackling noise, as is the case with bole; neither does a foaming take place, as has been copied by most authors from Cronstedt, who attributes this quality to a fullers' earth found at Ofmund in Dalarne.

Though fusible *per se*, it requires a high degree of heat: that of Hampshire, according to Klaproth, melted in the charcoal crucible into a dense, dark-grey, opaque slag, which had lost 0.25 of its original weight, and contained many grains of iron. In the clay crucible the same was reduced to a clove, blackish, green slag, with soft, reddish, punctated surface. Mr. Brongniart says, that of Woburn melted into a slaggy mass at 120° of Wedgwood's pyrometer. The variegated kind of fullers' earth (according to the late Mr. Wiedenmann's experiments,) acquired before the blow-pipe a grey, or greyish black colour; and a whitish variety, thus acted upon, became still whiter: but neither of them manifested any signs of fusion, except at the sharp edges of the fragments. The same appears to hold good with all genuine varieties of this mineral substance; whence the observation of the late Mr. Fichtel, that the true fullers' earth "melts with great ease before the blow-pipe, often with ebullition and increase of its bulk," is undoubtedly founded in error.

Bergmann was the first who analyzed what he styles fullers' earth, from Hampshire; and all subsequent mineralogical writers have followed him in mentioning that part of England as producing the substance in question: it is, however, probable that the accurate Swedish chemist was misinformed as to the county; though, from the satisfactory description he gives of its external characters, it is sufficiently evident that he operated on an English fullers' earth. The results of his analysis were

Silica	-	-	-	51.80
Alumine	-	-	-	25.00
Lime	-	-	-	3.30
Magnesia	-	-	-	0.70
Oxyd of iron	-	-	-	3.70
Water	-	-	-	15.50.

The variety lately analyzed by Klaproth, which is well ascertained to be from Ryegate, was found to be composed of

Silica	-	-	-	53
Alumine	-	-	-	10
Oxyd of iron	-	-	-	9.75
Magnesia	-	-	-	1.25
Lime	-	-	-	0.50
Muriate of soda	-	-	-	0.10
Water, &c.	-	-	-	24
Kali (a trace only)				

98.60. Klap. Beitr. vol. iv.

We are indebted to the same celebrated chemist for an analysis of a Silesian fullers' earth, the external characters of which agree pretty well with those of the other varieties, except that its colour is tile-red, like some varieties of bole, either pure, or spotted and veined with white and green; which colours, before the blow-pipe, give way to a marbled brown. Hundred parts of it contain

Silica	-	-	-	48.50
Alumine	-	-	-	15.50
Magnesia	-	-	-	1.50
Oxyd of iron	-	-	-	6.50
Oxyd of Manganese	-	-	-	0.50
Water, &c.				25.
Muriate of soda, (a trace only)				

98. Klap. Beitr. vol. iv.

We mentioned above the *Lemnian earth* as a variety of the common fullers' earth; but it should be understood that three distinct substances comprized by the ancients under the name of Terra Lemnia. Tre ejus," says Galen, signantur differentie una quam posuimus terræ facræ, quam alii nemian, præter unam sacerdotum, contingere fas est; altera vero ejus quæ revera Miltos est, i.e. Rubrica: utuntur autem ea potissimum fabri: demum tertia ejus extergit; qua utuntur qui lintea et vestes lavant, quibus itique collibitum est." The nature of the three kinds of earth alluded to in this passage has been placed in a clearer light by Klaproth. The *second* of them, called Miltos, was a red earth applied for the purpose of painting. The *third* appears to be the same which is mentioned by Pliny under the name of *Cimolia*, as an excellent substance for fulling; but it contains no magnesia. (See CIMOLIA.) But the *first* of the varieties enumerated by Galen, is the true *terra sigillata*, recommended as early as the time of Homer for the cure of infectious diseases, and still celebrated in the east for its imputed medicinal virtues. At the time of Dioscorides it was mixed by the priests with goats' blood, and marked with a stamp representing that animal (Σφραγὶς αἰγός); and still at the present day this substance is dug up in the island of Lemnos (now Stalimene,) once a year, namely, the 15th of August, the day on which the Greeks celebrate the festival of the ascension of the Virgin; the clergy and magistrates, after several previous religious ceremonies, superintend the excavation of this substance, which is immediately formed into spindle-shaped balls of one ounce in weight, and marked with a seal bearing the name of the earth in the Turkish language. This substance (which should not be confounded with a kind of bole of the same name, which is generally found nodulating in basalt and basaltic wackes) is of a whitish-grey colour, with ferruginous spots on its smooth surfaces. Put into water, it emits air, and soon crumbles into a loose heap, exactly like the common fullers' earth, to which, notwithstanding the slight difference in the results of the analysis, it may, according to Klaproth's opinion, be considered as subordinate. The genuine Lemnian earth contains in hundred parts

Silica	-	-	-	66.
Alumine	-	-	-	14.50
Oxyd of iron	-	-	-	6.
Lime	-	-	-	0.25
Magnesia	-	-	-	0.25
Natron	-	-	-	3.50
Water	-	-	-	8.50

99 Klap. Beitr. vol. iv.

The best fullers' earth is found in England, especially Buckinghamshire, Bedfordshire, Surrey, Kent and Nottinghamshire. The following localities are likewise mentioned in the different systems of mineralogy; but we cannot vouch for the correctness of all of them, since many substances have been called by the name of fullers' earth, that, systematically speaking, appear to have no claim to it. Austria (Karlsruhe, Götz); Croatia (Bilovar); France (Rittenau, Winterhausen, in Alsace, &c.); Hungary (Lufkarchen, &c.); Moravia; Neumark (Zulzenz, Drosken); Palatinate (Kelmstanz); Pomerania (Stargard); Saxony (Rosswein, Johan-Georgenstadt, Schönberg); Silesia (Riegersdorf, Nimptsch); Sweden (Ohrundberg); Stasia (Cilly and Thalberg); Switzerland (territory of Zurich and Berne); Transylvania (Thorotoko); Wirtemberg (Seiburg), &c.

The geognostic relations of fullers' earth are not yet sufficiently ascertained to enable the geologist to derive any general results from them. The relative age of the different formations appears to be as little understood, as the mode in which they have originated.

In Saxony, where it is found in extensive beds, it appears to owe its origin to the disintegration of rocks of the primitive trap formation of Weimar; that of Rosswein is subordinate to green stone slate. In the Upper Palatinate it alternates with layers of clay and porcelain earth. In England it occurs principally in beds, and in strata alternating with or resting on sand-stone, the geognostic relation of which is not yet determined. At Waverdon in Buckinghamshire, on the borders of Bedfordshire, where the purest sort is found, it appears to occur in the newer flint-formation, subordinate to sand-stone. From the surface of the earth, to the depth of six feet, several layers of sand are seen of various shades of reddish, under which there is a thin stratum of sand-stone which rests on the fullers' earth. The upper part of this latter, which is in contact, and mixed with the superincumbent indurated sand, is called *ledge* by the workmen, and thrown away as useless. To this succeeds a stratum of the good fullers' earth, being about eight feet thick, and subdivided by horizontal rifts into other layers of nearly one foot and a half in thickness. There is generally a ferruginous substance deposited on the rifts, which penetrates part of the layers; and the earth, so tinged, is called *crop* by the workmen, while the part unimpregnated by it receives the name of *wall-earth*. Under the fullers' earth is a stratum of coarse white sand-stone of about two feet thickness. The English fullers' earth is of much newer formation than that of Saxony; as is that of Moravia, which appears to belong to the alluvial formation.

The principal use to which fullers' earth is applied is indicated by its name, (see art FULLING.) The quality it possesses, of depriving cloths and other stuffs of the grease and oil used in their preparation, appears to be derived more from the argillaceous than the other ingredients; and Mr. Kirwan thinks that the union of the lime and magnesia (which in Bergmann's opinion is chemically combined with the alumine, and not mechanically mixed, as in marble) is useful only as contributing to the prompt diffusibility of this earth, which particularly qualifies it for the purpose to which it is applied. Every clay that has some unctuousity, (which manifests itself by the polish it receives by being rubbed with the nail,) and the siliceous ingredients of which are very fine, may be used for fulling; but it does not follow that all such clayey earths as agree in these two characters, and in the economical advantage derived from them, should of course occupy the same place in the system. Fullers' earth was formerly an article of the greatest import-

ance in England, whence its exportation was prohibited under severe penalties; but of late it has been superseded by other substances, particularly soap.—K.

We subjoin some observations on the subject of fullers' earth, communicated by Mr. Farey.

"This mineral is found in three places at least in the British series of strata, the uppermost of which is, in the sand strata that underlay the chalk, and are exposed to view by the great Kent, Suffolk, and Surrey *denudations*, (see that article,) at the foot or southern skirt of the North Downs, at various places near Ryegate, Godstone, &c. and from whence London is principally supplied with the article, though the quality of the earth and thickness of the seam (which varies much in different places) is greatly inferior to the next fullers' earth stratum, found near the lower part of the great ferruginous sand strata, (which Mr. Smith has denominated the Woburn sand,) in which fullers' earth is now dug in the greatest perfection, at Hogstye-end in the parish of Waverdon, Bucks, near Woburn. Formerly it was dug also in Aspley Guse parish, in Bedfordshire adjoining, but the works there are discontinued. Below this stratum of fullers' earth, which sometimes proves of seven feet in thickness for some distances together, is a singular greenish chert stone, with a rhomboidal fracture, which seems very characteristic of this stratum. In distant counties, like Lincolnshire, wherein we have examined it, about Bolingbroke, and to the N. and N. W. of that place, we find this and the accompanying strata very similar to those of Bedfordshire, although the fullers' earth is here so thin and imperfect in its quality, as not to be known by that name, but rather as a clay seam which holds up their springs of water in the sand district. It may also be worthy of remark respecting this fullers' earth stratum, that petrified or siliceous wood occurs in the ferruginous sand and sand-stone below it in great plenty and perfection, and furnishes most of the perfect specimens of this kind from Aspley, Crawley, and other places near Woburn, which are to be met with in the cabinets of the curious. How the stories of the petrifying springs at Aspley which occasioned them, as it is said, came first into circulation, we are unable to trace; but certain it is, that the inhabitants of this village disclaim any knowledge of such springs or petrifying waters, except what books and credulous travellers have brought to them. It has often occurred to the writer of this, that there might, at some period of the earth's formation and consolidation, have been a connection between the *flex* which abounds in such quantity and so very minute a state of division in the fullers' earth, and that which has so perfectly taken the place of the pieces of wood, lodged in the sand below it, and perhaps filled the interstices of the chert sand-stone above mentioned; but that such took effect, in too gradual a manner to be ever noticed as a petrifying spring on the surface, as the stories above mentioned have maintained. The examination of some hundreds of specimens of this petrified wood in Aspley and Crawley, some many feet in length, and a foot or more in diameter, has not seemed to furnish data for referring any of them to the known woods of the present race, or to contradict the theory advanced in our article COLLIERY, of such being part of the arborescent trunks of sub-aqueous vegetables of the primitive creation, whose *reliquia* they are, and by which alone their existence can ever be known to us, and not fragments of any of the trees which, now, or at any period, did occupy or grow upon the *dry land* of our globe.

"In Somersetshire and other counties, a stratum occurs between the rocks of the Bath free stone strata, which is there called fullers' earth, and possesses its scouring properties;

as indeed other strata do which are not called fullers' earth, particularly one in the assemblage of strata below the chalk, called the chalk-marl; from which a saponaceous whitish clay is got, and used by the country people for extracting grease, scouring greasy kettles, &c. There are doubtless other strata in the British series which possess these properties, in a greater or lesser degree, but the modern improvements in chemistry and the arts have rendered fullers' earth, of even the best quality, of comparatively small importance, to that which it had when particular statutes were judged necessary for prohibiting its exportation, under the severest penalties.

"Fullers' earth has been deemed absolutely necessary to the well dressing of cloth; and hence foreigners, though they can procure wool to be clandestinely exported out

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of the kingdom, can never reach to the perfection of the English cloths, &c. without fullers' earth, which is very plentiful in England, and excels that of other countries in quality, as much as in quantity and cheapness. For this reason it is made a contraband commodity; and the export made equally criminal with that of exporting wool."

This earth is reckoned by sir H. Plat, and others, a great improver of land; and consequently proper for being used as a manure where it is found in sufficient quantity for that application. It is probably the most adapted to the more high sorts of land.

FULLER'S *Tbistle*, in *Agriculture*, the common name of a plant cultivated in the field in some districts, for its use by the manufacturers of some sorts of cloth, as affording a fine vegetable hook, &c. See TEASLE.

Fullery & Fulling

FULLERY, a work-house, or place where cloths, &c. are full'd or scoured. The term is principally understood of the fulling-mill.

FULLING, the art or act of cleansing, scouring, and pressing cloths, stuffs, and stockings, to render them stronger, closer, and firmer; called also *milling*. See **BLEACHING**.

Pliny, lib. vii. cap. 56. assures us, that one Nicias, the son of Hermias, was the first inventor of the art of fulling: and it appears by an inscription quoted by sir G. Wheeler, in his travels through Greece, that this same Nicias was a governor in Greece in the time of the Romans.

The fulling of cloths, and other stuffs, is performed by a kind of water-mill; thence called a *fulling or scouring-mill*.

These mills, excepting in what relates to the mill-stones and hopper, are much the same with corn-mills. And there are even some which serve indifferently for both purposes; corn being ground, and cloths full'd, by the motion of the same wheel.

Hence in some places, particularly France, the fullers are called *millers*; as grinding corn, and milling stuffs, at the same time.

FULLING Mill, in the *Manufactures*, is a machine employed for washing, scouring, or fulling of cloth, either with a view of cleansing it, in which case it is termed *scouring*, or for the purpose of thickening woollen cloth, worsteds, &c. when it is termed *milling*; in either case the fulling-mill employed is the same: its operation is to constantly agitate and expose a new surface to the action of water or other menstria, with which the goods to be operated upon are constantly supplied; this is performed by two beaters or mallets, which are successively raised by the action of a water-mill, or steam-engine, and let fall upon the cloth, which they strike and turn over in the trough where it is placed; a constant stream of water passing through it, carries away the dirt and impurities which are loosened from the cloths by the agitation of the mallets, or stocks, as they are termed.

An inspection of *Plate XXIX. Mechanics*, will give a clearer idea of the construction of this machine. Here *fig. 4.* is a perspective view of a pair of stocks, or fulling-mill, in the action of scouring a piece of goods; the other figures are explanations of the parts of the machine by a section, *fig. 5.* and elevation, *fig. 6.* A fulling-mill generally contains four, six, eight, or ten pair of stocks, according to the quantity of work it is required to perform; these are all moved by the same water-wheel, or steam-engine: in the former case, the axis of the water-wheel is employed to move two or three pair, whilst the others receive their motion

from one of two similar and parallel shafts, turned by cog-wheels from the shaft of the water-wheel. A portion of this shaft is represented at *A* in the plate, beneath the floor of the mill; and the cog, which gives it motion, is denoted by *N*, *fig. 4.* it revolves upon gudgeons at its ends, which are supported on brasses resting on the frame work or masonry, as shewn in *fig. 6.* Four levers or lifters, *B, B, D, D,* are fitted upon the shaft which alternately, as they pass the beaters *E* and *F*, lift them up, and they descend by their own gravity: these beaters are formed from a large block of wood *E* and *F*, affixed to a long stem *G*, moving on a centre at *g*, which is supported at the top of the frame *H I K* of the whole machine; the principal part of this is a large block of wood *H I*, hollowed out into a large cavity *aa*, for the reception of the cloth; this is termed the trough. *K* are pieces of wood fixed to the piece *H I*, and curved to a segment of a circle struck from the centre *g*, on which the beaters move; in the spaces between these beams the stems *G* of the beaters project so as to be intercepted by the lifters *B, D*, as they revolve; the beaters are also curved at the lowest side to the same circle as the beams *K*, so that they apply as close as possible to each other without touching; this is necessary to prevent the cloth getting between them, and being pinched or cut thereby. The ends of the beaters, which act upon the cloth, are armed with three small boards at *b, i, and k*, *fig. 5.* which project like teeth, and act more effectually to bend and disturb every portion of the cloth placed in the trough *aa*. The beaters act very close to each other sideways, that the cloth may not introduce itself between them; and in the same manner they fit the sides of the trough, formed by boards nailed to the block *H I*, and the beams *K*, which also give a great strength to the machine. At one side these boards are not so high, for the convenience of taking the cloth out of the trough; but when the machine is in action a moveable board *M*, *fig. 4.* is placed on the top of the lowest side, to raise it to the same height with the other, and prevent any danger of the cloth getting over. *R* is a pipe bringing water to the trough, and furnished with a stop cock to regulate the supply; the pipe passes through the back of the block *H I*, and the water striking against a board *x*, placed before the aperture, it falls down in a sheet upon the cloth, and keeps it constantly saturated. When the cloth is to be put into the machine, a workman with a lever supported on an iron hook *k* receives the beater when at the highest point of its motion, and prevents its descent; he then thrusts a long iron bolt *r*, *fig. 6.* through a hole in the beams *K*, and by that means retains it; the other beater is then taken up in the same manner, and re-

tained by the same bolt, being pushed farther forwards; the loose board *M* is now removed, and the cloth thrown into the trough *aa*; the beaters are then set in motion by removing the bolt *r*, which held them up. As the shaft *A* revolves, the lifters alternately engage one or other of the beaters which fall against the cloth, and, striking it at the under side, thrust it up into the curved part of the trough *aa*, and by that means it falls down upon the head of the beater; when the lifter raises the beater another time, the cloth falls into the space left by its being raised; in this manner it continues turning the cloth over in the trough, and striking it by its teeth *b, i, k*, so as to wash it thoroughly. As the two beaters fall alternately, that is, one is up when the other is down, the cloth is also turned round diagonally in the trough; by this means, after mulling a piece of cloth for some hours, there is little chance but that every part shall be subjected to the action of the beaters, though a whole piece is in action at once, and consequently folded in innumerable creases. The water which enters at the upper end of the trough beneath the loose board *x*, (which is intended to spread the water out into a thin sheet, that it may fall equally upon the whole of the cloth,) escapes slowly through the grooves between the beam *K*, in which the stems *G* move, carrying with it all the filth contained in the cloth; it falls into a pit represented by the dark space in *figs. 5. and 6.* in which the shaft revolves. This pit usually has a communication with the water of the mill, to wash away the sediment which accumulates in the pit, from the foul water continually falling into it. The machine is fixed over this pit by a tennant at the lower part of the block *H I*, which is bolted between two beams *L, L*, supported on masonry; *M* are two braces to sustain the ends of the beams *K*, and keep the whole machine firmly in the same position: the beams *L, L*, are extended to a considerable length, and have three or four machines placed parallel to each other between them.

The true method of fulling with soap is delivered by *Monf. Colmet* in an authentic memoir on that subject, supported by experiments made by order of the *marquis de Louvois*, then superintendent of the arts and manufactories of France. The substance of which we shall here subjoin.

FULLING, Cloth and woollen Stuffs, with Soap, Method of. A coloured piece of cloth, about forty-five ells, is to be laid in the usual manner, in the trough of a fulling-mill, without first soaking it in water, as is commonly practised in many places.

To full this trough of cloth, fifteen pounds of soap are required; one half of which is to be dissolved in two pails of river or spring-water, made as hot as the hand can well bear it. This solution is to be poured by little and little upon the cloth, in proportion as it is laid in the trough: and thus it is to be fullled for at least two hours; after which it is to be taken out, and stretched.

This done, the cloth is immediately returned into the same trough, without any fresh soap; and there fullled two hours more. Then taking it out, they wring it well, to express all the grease and filth.

After the second fulling, the remainder of the soap is melted, as the former, and cast, at four different times, on the cloth; remembering to take out the cloth every two hours, to stretch it, and undo the plaits and wrinkles which it has acquired in the trough. When they perceive it sufficiently fullled, and brought to the quality and thickness required, they scour it out for the last time in hot water, keeping it in the trough till it be quite clean.

As to white cloths; because these full more easily, and in

less time, than coloured ones, a third part of the soap may be spared.

FULLING of Stockings, Caps, &c. may be performed somewhat differently; viz. either with the feet or the hands; on a kind of rack, or wooden machine, either armed with teeth of the same matter, or else with horses or bullocks' teeth.

The ingredients made use of herein are urine, green soap, white soap, and fullers'-earth. But water softened with chalk is far preferable.

Note, woven stockings, &c. should be fullled with soap alone; for those that are knit, fullers'-earth may be used with the soap.

Indeed, it is frequent to full these kinds of works with the mill, after the usual manner of cloths, &c. But that is too coarse and violent a manner, and is apt to damage the work, unless it be very strong.

FULLING, in the *Manufacture of Hats* is the completion of *felting* (which see), and has for its objects the intimate connection of the fibres, and a more perfect and durable cohesion of the whole mass. For this purpose the mere mechanical act of pressure is insufficient. In this way the result would be a formless mass, without consistency (says *Chaussier*, cited in *Nicholson's* *manuf.* vol. i.) has long shewn, that for the fulling of hats it is necessary to make use of a bath of water heated near to ebullition, into which are put 10 or 15 pounds of lees of wine, for each hundred pounds of water. The heat is kept up during the whole time of working, and every three or four hours a new quantity of lees is added. Into this bath the workmen plunge their felt, and begin their second process. The felt is dipped in, and immediately again taken out and squeezed, bended and rolled, by pressure in different directions, sometimes with the hand defended by leather, and sometimes by means of a roller or other similar instrument. The immersion and working of the felt are repeated, and the operation continued, till the stuff is well condensed, and has acquired the requisite solidity.

Since the operation of fulling is employed to form a dense and compact stuff with the fibres or hairs, and to determine the intimate cohesion of its component parts; and since the mere mechanical operation is not sufficient for this purpose, even with the assistance of a water-bath at the boiling heat, without the addition of lees as a necessary condition;—this last must be considered as a chemical solvent, which acts directly on the substance of the hairs themselves, and produces, either by softening or swelling them, an alteration necessary to insure the cohesion of the different fibres of the stuff. But the lees being composed of the mucilaginous and colouring parts, which are separated, together with a great quantity of tartar, or the acidulous tartrate of pot-ash, it became necessary to ascertain, in a positive manner, what might be the principle of its action. The editor of the *Encyclopédie* affirms without hesitation, that it is the alkali or pot-ash of the lees which determines the fulling. But in order to shew (says *Mr. C.*) how erroneous this assertion is, nothing more is necessary than to dip a piece of blue paper into the bath, by which the former becomes instantly red; and if, after several hours' work, the state of the bath be again examined, it is found that the acidulous tartrate of pot-ash is partly exhausted, and the workmen soon perceive, from the difficulty of continuing their work, that a new quantity is required to be added. And again, if we consider the sparing solubility of the acidulous tartrate of pot-ash in cold water, it is easily seen why in this process the water must be kept nearly boiling. Whence

it is evident that it must act by the portion of acetate which it contains. Hence our author was induced to think, that the sulphuric acid might be advantageously substituted in the place of the lees; and as 12 pounds of lees are usually added to 100 of water, he estimated by approximation that one gros of sulphuric acid would be equivalent to at least one pound of the lees, and consequently that 12 gros of sulphuric acid would be sufficient for 100 pounds of water. His conjectures were soon confirmed by experiment; and after a fair trial it was ascertained that the use of the sulphuric acid is much preferable to that of wine-lees; that it is not only much more economical, but still more convenient in the use; and, what is yet more important, the health of the workmen is not injured by the excess and duration of the heat, the thick vapours, and the disgusting odour, which exudes from the bath, particularly when the lees have been altered by mouldiness and putrefaction, which is very common in these manufactories. When the sulphuric acid is employed, it is useless to keep the bath nearly boiling, as was formerly done. A degree of heat of 25 or 30 degrees (55 or 105 of Fahrenheit) is sufficient for good fulling.

The saving of fuel is an object of importance in manufactories; and as very little fire is necessary when sulphuric acid is used, cauldrons of lead may be substituted instead of copper-boilers, the first cost and annual repair of which are very considerable.

The felts prepared by this new process are also of a very superior quality to those which have been worked in the bath with wine-lees. In fact, the mucilaginous and colouring matters of the lees, which are suspended in the bath, penetrate the texture of the stuff, and adhere with more or less force; and when, after having passed the hats through the dye, they are beaten, a fine black dust flies off in great abundance, which not only weakens the texture of the felt, but by diffusing itself through the manufactory greatly incommodes the workmen, and frequently occasions coughs and disorders of the throat.

Hats felted in this manner, says a manufacturer who had adopted this process, are not only clear of the powder which abounds in the others, but they take the dye better, and are cleaner.

Furnace

FURNACE, an utensil, or vessel, proper to contain fire, or to raise or maintain a vehement fire in, whether of coal or wood.

There are divers kinds of furnaces, of various forms, and for various uses.

The domestic furnace, used in making confections, &c. is usually of iron, or earth.

Those used by the goldsmiths, refiners, &c. are much larger, and of a different structure.

Those wherein lime, bricks, &c. are burnt, are called kilns.

FURNACE, in general, means a vessel or place in which high, or long continued heat can be applied in chemistry, in the arts, and domestic economy, and these are either fixed or portable.

Furnaces are principally divided into two kinds, those which act by the draught of a chimney and called *air* or *wind furnaces*, and those in which the air is forced in by bellows and called *blast* furnaces. But before we give descriptions of the different furnaces used in various chemical and other operations, we shall give a brief outline of their general principles, first premising that furnaces commonly consist of three distinct parts; a body, or cavity to contain the fuel, a chimney to carry off the heated air and smoke, and a receptacle under, and separated from the body by a grate,

and called the ash-pit. Although the construction of furnaces is a subject of the greatest importance to those employed in chemical and metallurgic operations, we yet do not find that any chemist or other philosophical writer has given principle, or any thing like a theory, from which rules might be deduced for the construction of a furnace of any kind, that should with certainty fulfil its intention; and a person, wishing to build a furnace, has hitherto had no other guide than that of taking the exact dimensions of some other furnace, that by mere guess has been so constructed as to act well. One fact we may use as a general rule, that is, that since the heat is generated by combustion, it must be the greatest when the greatest quantity of fuel is consumed in the least time, and when the fuel is in sufficient quantity, the heat will be in proportion to the quantity of oxygen passing through the fire in a given time.

In such a furnace as we have just pointed out, with a view to define the parts, if the fire be kindled, the air in that part will become specifically lighter, and will therefore ascend; the place of the ascending air must be supplied from below, and if there be no opening below, but through the grate, all the oxygen which enters must contribute to the increase of the combustion.

Every increase of heat will give an additional levity to

the air, and for a certain length of time the heat will continue to increase till it arrives at its maximum.

The velocity with which heated air ascends is as the difference of specific gravity between that of the atmosphere and the heated air. The principles on which the motion arising from a change of specific gravity may be referred to the case of two weights hanging over a pulley. If they are of equal weight no motion is produced, but if one be increased, or the other diminished, the heavy one will descend and the light one ascend, with a velocity proportionate to their difference.

If the sum of the weights be W and their difference P , then, according to Mr. Atwood's theorem, which he confirmed by experiment, the velocity at any point will be $\frac{P}{W}$ multiplied by the velocity which a body would acquire by falling freely through the same space.

The rising or falling of bodies in different fluids may be referred to the same calculation, by substituting their specific gravities for the absolute gravity of the weights.

Let ρ = the density of the surrounding air,

d = the difference of temperature between the surrounding and heated air in degrees of Fahrenheit,

P = the number of degrees of Fahrenheit required to double the bulk of a given quantity of air,

b = the height of the chimney,

S = the space a body will fall through in a second of time,

v = the velocity of the ascending air: then the increase of bulk in the heated air will be $1 + \frac{d}{P}$, and the density,

compared with the surrounding air, will be $\frac{P}{P + d}$. The

difference of density will be $1 - \frac{P}{P + d} = \frac{d}{P + d}$, and the

sum of their densities $\frac{2P + d}{P + d}$; then $\frac{d}{P + d} \div \frac{2P + d}{P + d}$

$= \frac{d}{2P + d}$. This fraction, agreeable to Mr. Atwood's

theorem, multiplied into the velocity a body would acquire by falling through b , will give the velocity of the ascending air;

$S : S' :: b : S'b'$; then $2S'b'$ will be the velocity a body would acquire by falling through b .

Hence $\frac{d}{2P + d} \times 2S'b' = v$, the velocity of the ascending current.

In finding d , let the temperature at the bottom of the chimney be B ; that at top T ; and let the temperature of the air which enters at the grate be M : then $d = \frac{M - B + T}{2}$.

The above theorem will require an equation for the friction of the tube, which will be very great in chimneys made of brick. It is plain that if it were not for the friction of the tube, the velocity would be as the square root of the height, all other things being equal.

In order to ascertain how far the friction of the tube affects the ratio of the square root of the height, I took (says the writer of this article) an iron tube of one foot long and two inches in diameter, having a funnel-shaped mouth, at the lower end, four inches wide, and about the same length. At the top of the tube was placed a small paper fly, with its

axis vertical, so that it might be turned by the rising current, in a manner similar to the fly of a smoke jack.

I found that a very small change of temperature was capable of putting the fly in motion. And that keeping both my hands upon the outside of the funnel, at the same time that there was free access of air into its mouth, I had constantly about 45 revolutions made by the fly in a minute. Reckoning the difference of temperature, or d , 45 Fahrenheit, which was about the fact, it would give by the theorem above stated the velocity about $\frac{1}{4}$ ths of a foot per second, which was near the truth.

The fly was then removed and placed at the top of the tube, lengthened to four feet. The velocity in this instance by the theorem should have been 75, but did not exceed five, so that the defect produced by the friction was .25. It would appear, therefore, that every increase of velocity, by increasing the height of the tube given by the theorem, may be divided by two, to reduce it to experiment. For the retardation by the friction, and the acceleration of its rising, are in the same ratio, that is, as the square root of the height. If, however, the velocity be increased by the change of temperature, or as d , then the friction will be increased in a greater ratio; for the friction is as the square of the velocity. Therefore, if the velocity be twice as great from increasing d , the friction will be four times as great. Hence the height of a chimney cannot increase the power of a furnace only to a certain extent, since the friction, after a certain limit, would prevent the acceleration, and bring the velocity to an uniform motion.

By other experiments I found that the manner in which the air enters the mouth of the tube is of some consequence. When the mouth of the funnel was held about two inches above the surface of a table, the current up the tube was hardly sufficient to put the fly in motion, and it would not begin to move till the mouth was elevated four or five inches. If, however, one-half the funnel rested upon the table, and the other over the edge of it, the fly went at the rate of 45 revolutions in a minute. When the funnel's mouth was covered with paper, having a hole in the middle equal to the area of the tube, 47 revolutions were produced; but when the whole mouth was exposed about the same height above the floor, it produced 49 revolutions.

It appears, therefore, that when the air can ascend freely and perpendicularly to the entrance of the furnace, it is to the greatest advantage.

Since, agreeable to the nature of our theorem, the velocity of the current must depend upon the difference of temperature between the internal and external air, the air entering the furnace ought to be as cool as possible. A furnace, therefore, should be so situated, that its air may be supplied from a cellar below, into which its ash-pit should terminate. This cellar should be as spacious as possible, and the ash-pit should be at least four times the width of the furnace, reckoning from the grate to the floor; but the higher the better, because the air, as we have before stated, is supplied with so much more facility in a perpendicular direction.

The grate of an air-furnace consists of a number of single bars, having shoulders at each end, so that when they are laid side by side, bringing their shoulders together, the interfaces between the bars may be nearly equal to the breadth of the bars. The distance between the bars is here rather more than is in common use, but for producing great degrees of heat, this account will be found to answer in practice. The bars are merely laid upon two bearers placed in the brick work at right angles to the bars; one of the bearers being loose for the purpose of sliding backwards to let all the bars fall down with the fire. Without this con-

trivance, after any process is finished, the fire would have to burn itself out, and it would be much more troublesome to clean the furnace when it is choked with slag.

The height of the fire-place must be suited to the purpose to which the furnace is applied. If it is a melting furnace, the height must be such that the fuel may be about half the width of the furnace above the top of the crucible, the latter being raised about $\frac{1}{4}$ th the width of the furnace above the grate.

The chimney of an air-furnace should be as wide as the sum of all the interstices through which the air enters the fire, allowing nothing for friction; but as this is very considerable, at least that ought to be double, so that the chimney should never be less than half that of the furnace.

The height of the chimney is the next consideration. In the present state of our knowledge we have no exact rule for the height of chimneys of furnaces. Indeed it will depend upon so many circumstances, that it would be difficult to give this statement exactly; since, however, the height is limited by the friction, it will be important to avoid all those circumstances on which the friction depends. The principal of these are, the roughness and narrowness of the chimney. The velocity of the ascending air will be inversely as the width; and the friction will be as the square of the velocity. It is equally certain that the friction will be much increased if the chimney be rough in the inside, but more particularly when it is crooked, or when the air is interrupted by having to move in any other direction than that of a perpendicular one.

When, therefore, the chimney consists of an upright prism or cylinder, having its interior surface as smooth as possible, it must act to the greatest advantage possible.

If the chimney be made of brick, those sides of the bricks intended to form the interior of the chimney should be rubbed to make them smooth, and laid with fine well-tempered fire clay, that the interior surface may be free from cavities and other inequalities.

If the chimney consists of iron lined with clay, it should consist of lengths of about two feet each. After each of the pieces are lined and well dried, but not hard baked, the inside should be scraped or rubbed, to give them greater smoothness. By this means the height of the chimney may be increased to advantage beyond the ordinary height; since the above pieces or lengths may be fitted together and separated with the greatest facility, and the maximum of height may be easily ascertained by experiment.

Another very important circumstance ought to be attended to in the construction of chimneys. The air which is heated in passing through the fire should retain its heat, if possible, till it clears the top of the chimney. Although this cannot be effectually accomplished, it may be effected as far as the non-conducting power of the materials of the chimney will admit.

Common bricks are very bad conductors, and consequently not well adapted for chimneys. But some fire-bricks of loose aggregation are still better calculated to retain the heat.

The best method, however, of making perfect chimneys, is first to build one of very close, smooth bricks, making the internal surface as above directed. This should be surrounded with a second chimney, leaving a cavity between the two about the breadth of a brick. This cavity should be filled with powdered coak, or, what is better, powdered charcoal. The heated air would retain its original temperature much longer in such a chimney, which would admit of its being carried higher, and increase the draught.

The chimneys of portable furnaces are generally made of rolled iron. These chimneys carry off the heat so rapidly,

that the height is very soon limited, and beyond that point becomes an evil. It has been recommended by Lavoisier to make the chimney of a double construction, and fill up the cavity with powdered charcoal. By this means, however, the internal tube would become so hot as to be easily acted upon by the air, and by sulphuring the fuel consequently would soon be destroyed. If the cavity between the two tubes were to be filled with a soft composition of equal parts of lime, clay, and sand, making the cavity between the tubes about half the width of the inner tube, an earthen tube would be formed, which would form an excellent chimney,

after the interior tube of iron was destroyed. The furnace itself, being lined to a proper moderate thickness with the above composition, would make a portable air-furnace of great power.

In those air-furnaces, where the fire-place is required to be open at the top, such as *Plate II. fig. 3*, the chimney is required to be connected with the fire-place by an horizontal channel called a flue. This flue must always be considered as being perpendicular to the draught of a furnace, and ought never to be divided, but where the separation of the chimney from the fire-place is absolutely necessary. From the experiments made on this subject, it will appear that the air of a furnace flue should be perpendicular as possible; hence a horizontal flue is sought in all cases to be avoided, and it will be equalled at that the evil will be still greater when the air is forced to turn, as in the furnace *Plate II. fig. 3*. In all furnaces, therefore, where the fire-place is intended to be separated from the chimney, the flue should be made to afford a much as possible by making an obtuse angle with the side of the furnace instead of a right one, as in *Plate I. fig. 1*. Various opinions have been advanced relative to the width of the flue. When we consider, however, that the flue is a part of the chimney, all opinions must give way, for if the flue is not as wide as the chimney the air must have to move with a proportional or greater velocity in that part, and in the same degree lessen the draught of the furnace. Hence the flue should be the width of the chimney as near as possible.

Although in strictness all furnaces are air-furnaces, yet, as we have above said, they are usually distinguished into those where the air is forced through the fire by bellows, and those where the air enters by what is called the draught of the chimney.

These are again denominated either from their construction, or the particular uses to which they are applied, as will be seen in the course of this article. Generally speaking, the furnaces used in chemical operations, and for melting and refining metals, are of the latter kind or air-furnaces; and we shall now proceed to describe the parts and particular uses.

FURNACE, Air. An air-furnace, calculated to produce great degrees of heat, particularly adapted for a melting furnace of the fixed kind, and possessing all the advantages to be given to it, is represented in *Plate I. fig. 1*; *a* is the ashpit of the furnace; *b* the grate; *c* the fire-place; *d* the cover, which consists of an iron frame filled up with fire brick. The cover slides sideways to open the furnace; *e* is in place of the flue of the common air-furnace, but here is made a part of the chimney *b*. The part *e* *f* *g* may be taken away without injuring the furnace, and the rest may be employed for many purposes, such as roasting substances, fitting crucibles upon it before they are introduced into the furnace; and occasionally a cupel may be set upon it, for the purpose of assaying metals, having at the same time a small opening in the cover *d*, for the purpose of admitting air. This furnace will be found much more powerful in not having a contracted flue, and at the same time making an obtuse

angle with the side of the furnace. From what has been previously observed, the high ash-pit will contribute much to its action. It is also recommended that the chimney should be double, and the interstices filled with powdered coak.

Fig. 2. represents a section of a portable air-furnace, adapted to general purposes: *a b* is a frame of cast iron standing on three legs; *c* a dish of rolled iron for the ashes to fall into; *a o* the top of the frame, has a hole in the centre a little wider than the fire-place, into which the grate is fitted; *d* is a groove passing quite through the frame, a little wider than the hole in the middle, and immediately under the grate. Different pieces of sheet iron are made to fit this groove, having different openings for the purpose of regulating the draught. One of them, however, has no opening, and is intended to shut out the air entirely. The openings in these regulating slides being in the centre, the air will enter the furnace perpendicularly, and its passage will be much facilitated by the height of the grate from the floor, and by the air having a free access on all sides to the furnace.

i k is the fire-place; *e* the cover, consisting of either one round brick made on purpose, fitted into an iron frame, or of several pieces fitted into the frame. The outside of the furnace is made of rolled iron, lined with a compound of two parts clay, two of coarse sand, and one of lime. The chimney is also of rolled iron, and consists of double tubes, *n o* and *p q*, riveted to the outside of the furnace. The cavity between the tubes is filled with the above-mentioned composition. The other parts of the chimney, when it is required to increase its height, may be made in pieces of about two feet in length, continuing like the parts attached to the furnace, of a double tube, and the cavity filled up as before directed. The inner tube must be a little shorter than the outer tube, so that the additional length of the outer tube may form the joint in putting the chimney together. A hole is made in the body of the furnace at *l*, and a similar one on the opposite side, for the purpose of introducing a tube through the furnace, which is required in many experiments. A slit is also made in the furnace at *k*, for the purpose of introducing the neck of a retort. The hole and slit above-mentioned have corresponding plugs made of the same substance as the lining of the furnace, by which these openings are closed when not wanted. There is another opening at *g* fitted by the plug *h*; this is used for the introduction of fuel when it is not convenient to introduce it at the mouth of the furnace. Occasionally, also, a small muffle may be introduced into it at this opening, the other end of the muffle resting upon the part *s*.

The cover being removed, a load-bearing may be introduced, similar to that in *Mr. Boulton's Plate II. fig. 7.*

When a retort is introduced, and the bottom does not happen to be supported by the ash, it is liable to move, and sometimes to be broken, by resting entirely upon the neck. This inconvenience may be remedied, by passing a solid plug through the furnace at *i*. This plug may be made by coating a piece of iron with a compound of very pure clay and sand, to render it as infusible as possible, since it will be exposed to the greatest heat of the furnace. The middle of this support must contain a recess to receive the bottom of the retort. When all the openings are closed, and a slide introduced at *a*, having an opening equal to the width of the furnace, this furnace will be found a most powerful melting furnace; and, by introducing different slides, it may be employed where the most moderate heat is required.

The air-furnace represented in *Plate I. fig. 3*, is principally intended for enamelling and assaying in the cupel, where the exclusion of every thing but the air of the atmosphere is par-

ticularly necessary: *a b* is an iron frame, similar to that of *fig. 2*, having a groove at *d*, for the sliding plates to regulate the draught, and a tray at *e* to receive the ashes; *g a y a* is the body of the furnace, made of rolled iron, and lined similar to that of *fig. 2*, leaving the space *mn* for the fire-place; *g p* is a dome connected at *p* by a sliding hoop, with the chimney *w*; *s* is a circular damper; *f* is a muffle, having a plug at *e*; *t* is the strong earthen tube standing upon the grate, having an opening, *l*, quite through it, which corresponds with a similar opening in the bottom of the muffle. This tube also serves as a support for the muffle; *x* is an opening through the coating of the furnace, corresponding with a similar hole in the end of the muffle. The end of the muffle is made convex, so as accurately to fit the side of the concave fire-place. Hence, a current of air will pass up the tube, *t*, into the muffle, which will escape at the opening, *x*, into the chimney *l*. This current can be regulated by the circular damper *q*. The plug, *e*, is only to be taken out to inspect the process, the damper, *q*, being at the same time shut to prevent the entrance of cold air into the muffle.

On each side of the dome are two openings, such as *b*, having plugs to fit. These are for the purpose of introducing fuel during the assaying process.

The advantages of this furnace, for the purpose of assaying, are obvious, since it can be regulated to the greatest nicety. When the current of cold air tends to cool the muffle, or the heat of the furnace is deficient, the damper, *q*, can be shut more or less; and if the heat is too great, that at *q* may be opened, and *s* shut to any degree.

This furnace may very easily be converted into a melting-furnace, or even to one for general purposes. The dome *g p*, and the muffle *f*, being removed, and a cap put upon the mouth of the chimney *w*, the furnace having a cover similar to that of *fig. 2*: the plug, *p*, being removed, will form the flue, the opening, *x*, being of no consequence, particularly when the damper, *q*, is shut; and a plug must be introduced at *e*, where the muffle was taken out. The chimney may be lengthened from the part *x* by pieces similar to those recommended in *fig. 2*.

An air-furnace, on the common plan, is represented in *Plate II. fig. 2*, in which *ac* is the fire-place; *e* the grate; *b* the cover; *d* the flue; and *c* the chimney. This furnace differs from the air-furnace already described only in the contraction of the flue, and the ash-pit.

A fixed air-furnace, invented by Mr. Knight, is shown in *fig. 3*: *a b c* is the air-pipe; *b* the grate; *c* the furnace for the air under the grate; *e* is the flue; *f* a cavity or chamber, for the purpose of baking crucibles, and other uses; *y* the passage for the air into the chimney *h*; and *i* is a sliding damper. Although this furnace possesses great conveniences, it is not calculated for producing the greatest degrees of heat, since the air must meet with much obstruction in its passage from the fire-place to the chimney. *Fig. 4.* is a furnace invented by Mr. Mufhet, intended as an experimental furnace for the purpose of assaying ores, &c.: *a b c d* is a cylinder of cast iron, lined with fire-bricks, so as to constitute the fire-place *e f*; *y* is the grate having a recess in the middle for the reception of a crucible stand; *s* the ash-pit; *o* is the flue, and *g h* the cover: *b i* is a rod of steel fastened into the bottom of the cast iron cylinder at *b*, and having at the other end an index *i k*, fitted to the arc *q r*, which is attached to the cylinder. When the furnace is used, the excess of expansion of the steel rod above the cast iron cylinder will give motion to the index, and if the arc be graduated, so as to correspond with Wedgwood's pyrometer, the degree of heat, in any experiment, will be known. In order to prevent the steel rod, which is polished, from oxydation, it is inclosed in a tube of

iron, and the cavity filled up with powdered charcoal. The fire-place, from the grate to the cover, is three feet; the diameter at the grate ten inches, and at the top nine inches. The height of the chimney, the inventor recommends, should not be less than thirty feet, and the width nine inches throughout.

Although this furnace has not been generally adopted, the thought is very ingenious, and, no doubt, practicable, to a certain extent. The scale would most likely require to be altered from time to time; first, from the change in the expansibility of the steel rod; and, secondly, from the increase of the conducting power in the bricks. These objections may be much obviated by attending to these changes. At all events, the pyrometer will enable the operator to find the relative heat, should it even fail in measuring the absolute degrees, which will certainly be a great acquisition.

Dr. Black's reverberatory air-furnace is shown in *Plate II. fig. 1*: *ab* is the fire-place; *b* the grate; *c* the cover; *ac* is an horizontal cavity through which the flame reverberates, and passes up the chimney *l*; *d* is a door for introducing the materials to be operated upon.

This furnace is used for roasting various substances, such as the ores of metals, for the purpose of expelling their volatile matter. It may be also employed for the cupellation of metals, the door *d* being a little opened for the admission of atmospheric air.

Fig. 5. is a representation of Mr. Knight's portable air-furnace; *ab* is the fire-place; *bc* the ash-pit, which is closed on every side, excepting at the register door, where the air is admitted; *o* is an opening for the reception of fuel; *e* is a recess for the neck of a retort. *Fig. 9.* is a dome fitting the top of the furnace, to which the tube *fig. 10.* is connected, which unites with another tube inserted into a common chimney. *Fig. 8.* is a sand-bath, which is used in the absence of the dome, and, like it, is connected with the tube *10.*

This furnace is made of rolled iron, and lined with an earthy composition. *Fig. 6.* is a perspective view of Dr. Black's portable air-furnace, which, but for its confined ash-pit, has not as yet been improved upon: *ab* is the fire-place; *bc* the ash-pit; *e* a sliding door for the admission of fuel, &c.; *d*, another door for the same purpose, and also for the introduction of a muffle. *Fig. 11.* is a cover, and *fig. 7.* a sand-bath; *f* is a chimney, which is lengthened by pipes of rolled iron, or connected by the same with another chimney. This furnace, like the last, is made of rolled iron, and lined with clay and sand.

Another air-furnace, of great power, and very convenient for operations, has been constructed and employed by Mr. Musset in his numerous and valuable experiments on iron and steel, a portion of which he has communicated to the public through the medium of the *Philosophical Magazine*: he has obligingly furnished us with the drawing and description. *Plate III. fig. 1.* is the section of an assay or melting, and annealing, and also a small reverberatory furnace for fusing in very high heats with the flame of pit-coal. *A* is the assay-furnace; *B* the reverberatory furnace; and *C* the annealing, or cementing-furnace.

The assay-furnace is cased in cast iron, with a flanch projecting inward, the breadth of a brick, and about half an inch more, which serves instead of bearers for the bars. (See *fig. 2.* at *D.*) Upon this flanch the brick-work is reared; it ought to be of good fire-bricks on the bed; the furnace is nine inches square; total height 27 inches; from the top of the flanch, to the bottom of the flue, the interval is 18 inches; the flue is four inches high; the height above is five inches; flue seven inches long, and keeps opening into the chimney, as may be

seen in *fig. 3.*, at *E.* If the chimney is under 25 feet in height, a larger flue is requisite; and if beyond 35 feet, a smaller flue will throw the heat more regularly through the furnace. In general, however, more harm ensues from too small, than from too large a flue. *G* is the floor-line, and also represents the edge of a grate which covers the ash-pit, which is better seen in the ground-plan, *fig. 3.*, and in *fig. 2.*, at *H.* This grate lies nine inches from the bars, leaving an open space for the admission of air; it projects 24 inches outwards, and serves the operator to stand upon.

II., in *figs. 1* and *2*, is the ash-pit; in *fig. 3.*, which is a ground plan of the chimney and furnaces, *C* is the annealing, or cementing-furnace, in which the crucibles are annealed, or baked, to a bright red heat, and from thence introduced, along with the matter to be operated upon, into the assay-furnace. It also serves instead of a cementing-furnace, being easily made to produce a heat of 100° of Wedgwood: it may be made of any size, from 9 to 14 inches square, a 9-inch chimney being sufficiently wide to the extent of an 18-inch furnace.

The chimney to each furnace is carried up five feet perpendicular; they then gradually incline to the centre opening, which they enter about twelve feet above the flue: *L, L, L.*, are dampers: from the grates of this assay-furnace, to the top of the chimney, the interval is 33 feet.

This furnace has melted 400 grains of malleable iron in ten minutes; and half a pound from lumps in 40 minutes. If the materials to be operated upon are prepared with judgment, any experiment, to the extent of half a pound of matter, may be performed in half an hour, and less quantities in much less time. When approaching to its highest heat, a Stourbridge clay crucible (which drop in 168° of Wedgwood,) will disappear in 15 minutes, from the time that it is put in. The first five bring it to 140° of Wedgwood, at which cast iron boils. Steel boils in it at 162°, and malleable iron boils at 170° to 172° of Wedgwood. It is probable, however, that the advantages of this furnace do not result from the height of the chimney, (which is not great,) or from the size of its opening; more, it is likely, depends upon the flue; the opening of the grate bars; the size of the fuel; and particularly the feeding of the fire.

FURNACE, Almond, or Alman. This is also called a sweep, and is used for separating metals from cinders, slag, broken tests, crucibles, &c. See SWEEP.

FURNACE, Assay. The furnaces above described may all be used for assaying or cupelling, see *Plates I, II, III.*

FURNACE, called albanar or tower furnace. This was a construction of air-furnace, calculated to preserve an equable degree of heat for a considerable length of time; it was much employed by the alchemists and chemists of the last and preceding century in their tedious and repeated distillations, calcinations, &c. but is not at present in use.

FURNACE, Balling. See IRON.

FURNACE, Bellows or Blast. Having given an account of the principles, and described the varieties of air, or draught furnaces, we shall give some account of those furnaces which are supplied with their air by mechanical means, and are called blast-furnaces. This part, however, will not comprise those on the large scale for smelting iron, as that subject has been amply treated under the article *BLAST-FURNACE*. We shall, therefore, confine ourselves to the smaller blast-furnaces employed in chemical experiments requiring great and sudden heat.

It will appear, from what has been observed respecting the principles of furnaces, that if the ash-pit of a common air-furnace were made perfectly close in every part, excepting through the grate, and an opening into the ash-pit into which the nozzle of a pair of double bellows may be in-

ported, a blast-furnace would be found differing from an air-furnace only in the mode of forcing the air into the fire. Indeed its action would be so similar to that of an air-furnace, that it might for most purposes answer the same end.

The blast-furnace for philosophical experiments was much improved by the ingenious Dr. Lewis, who fitted up a black-lead crucible for this purpose. The pot chosen should be of the largest size, and if a cover or dome, or an additional part be wanted, another pot with a portion of its lower narrow part sawed off makes a very convenient one. A round plate or slip sawed off from the solid part of the bottom serves very commodiously both for a grate and for a support to the crucible; eight or nine holes, about three quarters of an inch in diameter, are bored round the outer part of the plate for the transmission of the air forced in by the bellows, which holes are made to widen downwards to prevent their being choked up by pieces of the fuel. The air was forced in by bellows by an aperture on the side of the pot.

In operations which require a considerable degree of concentrated heat, it has been proposed to impel a number of flames into one point by streams of air driven from different parts of the circumference of the fuel to the middle by means of several bellows placed round the furnace. But a number of bellows being inconvenient, Dr. Lewis has contrived to multiply the stream of air from one bellows. The pot which serves as a furnace for this purpose has a number of holes bored at small distances in spiral lines all over it, from the bottom up to such height as the fuel is designed to reach to.

The crucible is placed on a proper support in the bottom; and the holes are obliquely directed towards the crucible, so that the impelled heat plays in a kind of spiral upon its surface. The pot which serves for the blast furnace already described, with an iron ring at the top, receives this perforated pot so far, that all its holes are within the cavity, which cavity has no other outlet than the round aperture for the bellows; and therefore the air thus blown in will distribute itself through the perforation of the inner pot.

Mr. Arthur Aikin has considerably improved upon this plan of Dr. Lewis's, and the following is a description of his furnace, as published in the *Philosophical Magazine*.

Plate IV. fig. 3. is a view of a section of this furnace. It is formed of three black-lead crucibles. The 1st, *a*, is a crucible cut off near to the bottom, leaving a portion of the internal cavity; the 2d, *b*, is what contains the fire and the crucible. The bottom of this crucible is perforated with holes for the admission of air, as shewn at *fig. 4*, which is blown into the cavity in the base part *a*, by double bellows. The stand of the crucible has a projecting part which fits a hole in the bottom of the crucible *b*, in order that it may stand more firmly (see *fig. 5*.); *c* is a third crucible sometimes inverted upon that of *b*, when the fire requires to be heaped up higher, or to keep off the glare of light. This has a hole in the side to let out the air, and another into the bottom laterally, for the purpose of introducing an iron instrument to lift it on and off.

This furnace is particularly adapted for a lecture room, since its fire can be raised to its full heat in a very little time; at the same time it is capable of producing a greater heat than almost any other furnace.

Mr. Aikin has adapted this furnace to experiments with the cupel, by having a crucible with a hole through the bottom, and a stand having a corresponding hole through it, communicating with the cavity in the part *c*. In the inside of the crucible are several projections forming a shoulder or flange to set the cupel upon. An earthen tube is fitted into

the cover extending obliquely out of the mouth of the furnace; this serves to look down for inspecting the process.

Several kinds of small blast furnaces are also used in the arts, particularly that used in melting pig iron for the purpose of casting. This furnace is called a cupola, and will be described under iron. See IRON.

FURNACES for making Colours, are those for subliming cinnabar or sulphuret of mercury for making vermilion; for subliming sulphuret of arsenic for making king's yellow; for calcining blood for making Prussian blue, ochre, &c. &c. For their construction and use, see the arts, and the different articles in this work.

FURNACE used for enamelling Pictures. The extreme delicacy which is necessary in the process of firing or burning in the colours in enamel painting, renders the construction of the furnace an object of the utmost importance to the artist, whose labours are liable to be irrecoverably lost by the slightest mismanagement of the process, or error in the formation of the furnace.

We are enabled, through the kindness of Mr. Bone, of Berner street, London, enamel painter to the king and prince of Wales, to present our readers and artists of this class with a drawing of the furnace which he has employed for firing his most celebrated productions, and which, we may safely say, have not been equalled either for the richness of colour and accuracy of design, or for the size to which he has extended the paintings on enamel, which were formerly confined to the most minute subjects. The lower part of *Plate V.* contains these drawings, which are two vertical sections taken on planes perpendicular to each other; the same letters of reference applying to both. *A* represents the fire grate extended over the ash-pit, *B*, of the furnace; the fire door at *C* for the admission of the fuel is placed at the back of the furnace or side opposite to that where the operator is stationed, and in a separate room: this is intended that the smoke, which will at sometimes issue from the mouth of the furnace, may not endanger the pictures. The room, therefore, where the operation is performed, has no connection with the fire, so that the whole may be conducted without dust or smoke. The pictures are placed in a muffle *E*, which is open only at one end; it is supported upon three small arches, *F, F, F*, of brick-work extending across the furnace; the spaces between these form three flues, which convey the flame of the fuel beneath the muffle. The mouths of these flues are shewn by the three dark squares *fig. 11*; they then turn up over the arched roof *K*, of the fire-place, and under the muffle between the arches *F, F, F*, at the commencement of these flues shewn by dark squares in *fig. 11*, and marked *a* in *fig. 10*. The flame divides, and a part proceeds over the muffle at *b*, being reverberated upon it by the arched roof of the chamber in which the muffle is situated. After passing over and under the muffle, the two currents of flame escape together to the chimney *N*, through three flues *d*, which are beneath an iron chamber *H*, called the annealing oven. In this four shelves are fixed to contain the articles which are to be annealed, previous to being introduced into the muffle. This is done through the open end which is exposed at *e* to the open air, the junction of the muffle with the wall of the furnace being made by fire clay inserted between them. Before the mouth of the muffle an iron plate, *f*, is placed supported by brackets: this, together with the wall of the furnace, forms a table to support the picture when it is withdrawn from the muffle for examination. The muffle is made of fire clay in one piece, but it is very difficult to obtain materials which will withstand the heat when in so large a mass without cracking, which the best that can be procured

will do; frequently it, however, is not a very material defect, if a small crack takes place at the upper part, as it begets a confidence that the muffle will not crack any further, owing probably to the unequal contraction of the parts of the muffle having liberty of action.

The operation of burning in the colours of a painting, or, as it is technically termed, *firing*, is conducted in the following manner: the picture painted, and prepared as described in our article *PAINTING in Enamel*, is placed upon a planch or flat piece of fire-stone, with a small quantity of whiting between them, the use of which will be explained hereafter. These are put into the lowest shelf of the annealing oven H, and the door of the oven closed to prevent the entrance of dust. The fire is now lighted on the grate, and after burning from three to four hours, according to the state of the weather and direction of the wind, the muffle acquires a vivid white heat, and of similar appearance in all parts: when this happens it is judged proper to begin firing; the pictures in the oven in the mean time have gradually acquired such a heat as to be in no danger of cracking from the change of heat on entering the muffle; the planches have usually reached a low red heat by the time the muffle is properly hot; and it is supposed that the oil used in mixing up the colours is nearly all evaporated, the painting exhibiting a very dull and faint appearance. It is proper that the door of the annealing oven should not be too close, that the vapour from the oil may readily escape.

The planch and picture upon it are now removed from the annealing oven by an iron fork, *fig. 7*, used in a manner similar to a baker's peel, and introduced into the muffle: the doors are shut close; the operator now looks through a small hole in one of the doors, furnished with a sliding cover, and attentively watches the picture; he sees it gradually heat till it acquires the same colour as the muffle; the surface of the picture is then observed to assume a glossy appearance, arising from the fusion of the enamel; at first this commences at the farther part of the muffle, but extends itself, with astonishing celerity, over the whole surface, if the operation is well conducted. The picture is now withdrawn from the muffle upon the table before its mouth, and examined before a strong light, if every part is equally glossy; if not, it is returned to the muffle; in this state the picture and planch only exhibit a mass at a white heat; no traces of painting or colour can be discovered, and the whole judgment must be formed from its appearing equally fused in every part of the surface.

The fusing being now completed, the picture is returned to the annealing oven; and the fire being put out by taking away the bars of the fire, the whole furnace cools gradually together, the picture remaining in the oven some hours before it is removed to paint again upon it. The operation of firing a picture requires to be performed from twelve to twenty-five times, according to the tints required, and the nature of the picture: the pictures are liable to crack whilst in the muffle, an accident that cannot often be repaired, in which case the labour of painting is all lost. The principal precaution against this is to proportion the flues in such a manner that the annealing oven shall always be of such a temperature that the pictures taken from it, and introduced into the muffle, may not experience such a change of temperature as to fly. In Mr. Bone's furnace this is so well regulated, that he seldom finds his paintings crack in the firing, though it cost him many severe disappointments before he obtained this perfection by repeated trials: this disposition to crack appears to depend almost as much upon the plate and enamel as the construction of the furnace, and it is no proof because a painting stands the first firings well, that it will

not fly in the succeeding. Enamel pictures are nearly all liable to cockle or warp in the firing, in a greater or less degree, though this may be obviated so far, by great care in the preparation of the metal plate, as to be no serious detriment to the effect of the pictures: the method of preparing these plates is explained in the article *ENAMELLING*. For an account of the colours, and art of painting, see *PAINTING in Enamel*, which is a subject requiring long experience, to be added to the usual knowledge of a painter, as the colours are in fact produced by the firing, being very different in appearance when laid on, and without any of the brilliancy for which this species of painting is distinguished. The artist must judge concerning the effect which his painting will produce by his recollection of the change of each colour, and its combination with others, instead of being able to examine it constantly by its appearance: but it is essential to the perfection of enamel painting, that all the colours employed should blend together in the firing, and at the same heat, or some would be too much burnt before others were properly fused; and they must be of such a nature as not to emit any vapour when in the fire, as this would produce bubbles in the surface, and destroy the effect of the painting.

As the colours at present known which will stand these tests are but few, and require compounding together to produce the various tints, it is an additional reason why none can be admitted but such as are acted upon in a similar manner by the fire. It is conjectured that the crack in the muffle, being found rather to improve than lessen the effect, may arise from a minute draught which will take place through the muffle, carrying off any vapours proceeding from the oil, which may remain in the colours after annealing, or other causes, which vapour, if confined to the picture, might be detrimental to the colours. As the generality of enamel plates are made with the surface convex, it becomes necessary, when they are large, to support the centre of the plate from sinking, which they are very liable to do when in a state of fusion. To prevent this accident, the planch must have a bed of powdered whiting laid upon it, with its surface made to fit the concavity of the enamel plate as nearly as possible, carefully avoiding all pressure upon the plate, least it should receive any strain. If this operation is nicely conducted, the plates may be made to keep their shape much better than by any other means that have as yet been devised.

FURNACE for enamelling watch Dial-plates. This furnace, though very simple in its construction, differs from all the others we have described in not having any bars or grating for the admission of air to the bottom of the fire; the only passage for air being through or under the muffle, which in this kind of enamelling consists only of a simple arch of clay without either bottom or back.

This furnace is singularly adapted to the purpose for which it is used, as a very intense heat is obtained with a comparatively small quantity of fuel, in addition to which the work may be brought almost in contact with the coals without receiving any injury from their dirt; cleanness in this kind of enamelling being very justly considered one of its greatest perfections. *Fig. 1. of Plate V. of Furnaces*, represents a front elevation; A, A, are two piers of brick work, upon which rest the arch B, covering the ash, or coak-pit, C. From each side of these piers project the three bricks D, D, D, which support the hearth, or iron plate, E; another plate of cast iron lies just beneath this, which serves for the bottom of the furnace, and which may be seen in the section at F, *fig. 2.* Upon this plate of iron stand the Welsh lumps, G, G, forming the interior sides of the furnace; the one which forms the back may be seen at G,

fig. 2 : the brick-work is then carried upon each side over the piers, and bound together by the iron bar H, which likewise serves to support the brick-work over the front, in which is fixed the regiter, or damper, I. When the furnace is completed thus far, the flue may be carried up to a convenient height, or turned into one already formed.

To give the reader a clear idea of the method of using this furnace, as well as the way in which the fuel should be placed, we have given, *fig. 2*, a vertical section through the line C I, perpendicular to the front; and that the parts in each may be compared, we have used the same letters of reference as far as the parts could be seen in each figure.

When the fire is to be made up for use, the muffle is to be placed in the furnace; one end resting on the iron support, as shewn at K, *fig. 1*, and the other end is to be kept level with the front by putting a piece of coak under each side. The space on each side is then to be filled with small pieces of coak, and at the back of the muffle small coak must likewise be put in till it reaches about half way up the end. A solid piece of coak must then be selected, which must be large enough to cover the end of the muffle, and upon this a second piece must be placed to supply the place of the first when that is burned away. The space then immediately above the muffle must be filled with middling sized pieces of coak, carefully building it up in the front, so as to keep it even with the sides G, G. The door, as shewn at *fig. 3*, is then to be placed in the front, pressing it close up to the sides G, G. To light the fire, nothing more is necessary than to fill the space under the muffle with red-hot charcoal, and by drawing the damper a good way out the fuel will soon be alight all over. In *fig. 2*, it will be found that we have endeavoured to shew the position of the fuel placed in the order of our description, with a section of the muffle shewing the height of the charcoal which lies at the bottom when the fire is in a state fit for use. For we must here observe that it will be always necessary to beat that pretty smoothly down, that the apparatus which the dial lies on may be placed steadily upon it.

As it would be difficult in this figure to shew the position of the dial-plate in the fire, we have given, at *fig. 8*, a section of the apparatus as it is placed under the muffle; *a* being the dial-plate; *bb*, the ring; *c*, the planch; *d*, the turner. In using these, the turner is first placed steadily upon the bed of charcoal, and the dial, being placed upon the ring is laid as nearly as possible in the centre of the planch, which is conveyed under the muffle, and placed upon the turner with the spring tongs, as shewn at *fig. 6*. When one side of the plate is nearly melted, the planch may be turned round by a slight touch with the tongs, till the whole dial is completely fused all over, when it must be withdrawn from the furnace, and placed just in the front of the muffle to cool gradually.

Fig. 4, is an end elevation of the muffle placed on the prop, as shewn at *fig. 1*.

Fig. 5, is a vertical section of the same through the line *ab*.

Fig. 9 is the iron key with an aperture in the end, which fits the square pin, *e*, in the door, as shewn at *fig. 3*, and is used to remove the door from the front of the furnace when it is hot.

FURNACE, *Founders*, is of different forms, according to the kind of works to be cast. See **FOUNDRY** and **IRON**.

FURNACE, *Glass-House*. See **GLASS**.

FURNACE for *Glass-Painters*. See **PAINTING on Glass**.

FURNACE, *Hatters*. See **HAT**.

FURNACE, *Lamp*. See **LAMP**.

FURNACE, *Letter Founders*. See **LETTER-FOUNDRY**.

FURNACE, *Melting*. See **Air-FURNACE**.

FURNACE, *Plumbers*, is of three kinds: in the first they melt the lead, whereof sheets are to be cast. This is only a sort of large copper, or receptacle like a copper, made of fire-stone, and coated well round with clay, having a little iron pan at the bottom. In the second, they melt the lead to be cast in moulds for pipes, &c. which are not to be soldered. The third is the tinning furnace, which is a square frame of wood, or sometimes a mass of stone-work, with brick hearth, whereon is made a charcoal fire, which serves them for the applying of thin tin leaves on the works. See **PLUMBERY**.

FURNACES for *baking Porcelain and Pottery*. See **KILN** and **PORCELAIN**.

FURNACES, *Portable*. See above, **Knight's**, **Black's**, **Lewis's**, **Musket's**, **Aikin's**, &c.

FURNACE used for *baking Tobacco-pipes*. We may, perhaps, be criticised for introducing into our plates the implements of so trifling a manufacture, but we shall excuse ourselves, on account of the ingenious structure of the furnace, and the application which may be made of it to other and more important purposes. This furnace is to be admired for equality of the heat in every part of the crucible, or pot, in which the pipes, or other articles to be heated, are placed, at the same time that the flame is not permitted to enter, so as to soil the articles it contains. This crucible is marked A A, *Plate III. figs. 4 and 5*: it is of a cylindrical figure, terminated at the top by a hemisphere; it is placed over the fire-place, B, and enclosed within a furnace, D D, of brick-work, lined with fire-brick E E: between this lining and the crucible is a space of about four inches, all round in which the flame from the fire-place circulates, without interruption, except what arises from the numerous supports which are necessary to sustain the crucible in its proper position; but as these are always placed edge-ways to the flame, and are very thin, they cause but little obstruction to its action: the supports are 12 ribs, between the crucible and the lining, which form the same number of flues, as shewn by the dotted lines *x*, *fig. 5*, (the dotted circle A being the crucible): the ribs are perforated with occasional apertures, (see the section, *fig. 4*.) to connect one flue with the adjoining; but the principal bearing of the crucible is taken from five piers, *bbc*, formed of bricks, projecting one over the other: one of these piers, *c*, is placed at the back of the fire-place, and the other four at the sides *b, b*, and projecting at the top, nearly into the centre of the crucible, so as to support and strengthen the bottom of it, which rests upon these piers, the spaces between which form the mouths, or commencement of the flues surrounding the crucible: at the top of the crucible all the flues unite in the dome, L, of the fire-brick lining, and this has a circular opening through it, leading into the chimney N.

The lining, F E E, of the chimney is open on one side, (see the plan,) to form the door, at which the pipes are taken in and out of the furnace; the opening is permanently closed as high as *k*, *fig. 4*, by an iron plate plastered with fire-clay; above this it is left open, and only closed when the furnace is burning by temporary brick-work: when this is removed, the furnace can be filled or emptied through the opening; and, for this purpose, the crucible has a similar opening in its side: when the furnace is burning, this aperture is closed, by an ingenious contrivance: the workman first spreads a layer of clay round the edge of the opening; he then sticks the stems of broken pipes across, from one side to the other, and plasters the interstices with clay in a manner exactly similar to the lath and plaster used in building. The whole of the crucible is made in this manner; the bottom is composed of a great number of fragments of pipes, radiating to

the centre ; these are coated with a layer of clay at the circumference ; a number of the bowls of broken pipes are inserted into the clay : in these, other fragments are placed upright, to form the sides of the crucible. The ribs round the outside, which form the flues, are constructed in the same manner, as is also the dome, *L*, of the fire-brick lining ; by this means the crucible can be made very strong, but at the same time so thin, as to require but little clay to construct it, and is less liable to split by the heat, than a vessel formed of thicker materials. This method might, we think, be advantageously applied in other cases, where a very thin vessel or lining is required for a furnace. The pipes which are to be baked are arranged within the crucible, as shown in the section, the bowls resting against the circumference, and the other ends supported upon circular pieces of clay, *r*, which are set up in the centre for that purpose ; six small ribs are made to project inwards, all round the crucible, at the proper heights, to support the different ranges of pipes, without having so many resting upon each other, as to endanger their being crushed by the weight. By this mode of arrangement, the furnace is made to contain 50 grofs, or 7200 pipes : these require to be burned from seven to nine hours ; and the heat is at first brought on gently, and afterwards increased to the full heat required for baking this species of pottery : the fire is regulated by a simple kind of damper applied over the aperture in the dome, *L*, of the fire-brick lining. This is a mixture of horse-dung, sand, and pipe-clay, well worked together, and spread in thin layers upon coarse brown paper : a sheet of this being laid over the hole in the dome, so as to cover more or less of it, will give the means of increasing or diminishing the draught, and, consequently, the heat of the furnace.

We shall conclude this article with some useful hints relative to the different kinds of fuel, the management of furnaces, and the quality and form of crucibles.

The fuel employed is of three kinds ; namely, pit-coal, coak, and charcoal ; the first of which is seldom employed but for reverberatory furnaces, where substances are to be heated by flame, or heated air. The nature of coaks varies according to the manner of preparing them, and the nature of the coal. For some purposes, such as melting steel, or in other situations, where long continued and intense heat is required, the coaks are made so hard as to exhibit a bright, white, crystalline fracture. In other cases, where great heat is not required, and where expedition is more an object, the soft coaks are preferable. When a clear fire, free from smoke, and the suffocating vapour of sulphurous acid, from pit-coal coak, is required, charcoal is found exceedingly convenient. Charcoal is also sometimes mixed with coak, for the purpose of making the coak kindle more speedily.

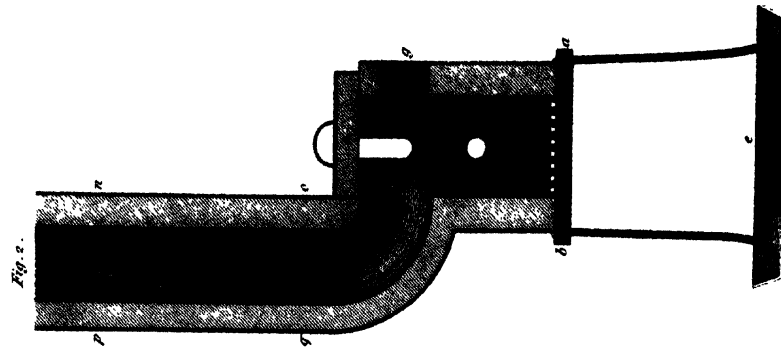
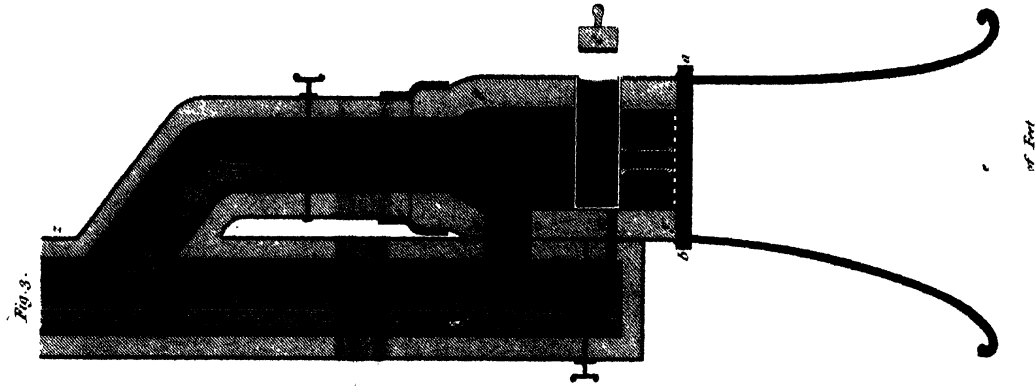
When coak, or pit-coal, is employed, the grate is liable to be choked, from the fusion of the earthy matter with which it mostly abounds. An iron rod, with a hook at one end, is used for removing this substance from the grate, which otherwise would prevent the passage of the air. After an air-furnace has been used for several hours, when the fire is let out, the bars ought to be taken out for the purpose of removing all the slaggy matter.

Nothing, perhaps, is of more importance, in the dry operations of chemistry, than good crucibles. Formerly we had no good crucibles but what came from Holland, and those termed Hessian crucibles. The most essential point in making good crucibles, is to get clay as free as possible from metallic oxyds, particularly iron. A crucible should be capable of bearing a heat that will thoroughly fuse the substance put into it, without becoming itself so soft, as not to bear lifting out of the fire. And it should also be capable of bearing sudden extremes of heat and cold, without cracking. The first of these objects is attained, by introducing as much pure clay into its composition as possible. Crucibles, made solely of clay, however, are very liable to crack with extremes of heat and cold. This latter evil has been avoided, by mixing the coarse powder of burnt clay with the pure clay ; and sometimes for the burnt clay pure white sand has been used. The crucibles used for melting steel, which requires greater heat than is generally used, are made with Stourbridge clay, and the powder of other hard coaks, which are used as fuel. These pots will sometimes bear four heats, or meltings, without cracking or losing their form.

The inside of a crucible is in figure nearly a paraboloid, and the outside a truncated cone ; so that the sides are gradually thicker towards the bottom. The stands and covers of crucibles ought to be made of the same materials as the crucibles : the stand should be cylindrical, and of the diameter of the bottom of the crucible.

Previously to a crucible being put into the fire, it should be gradually heated to at least a low red heat ; and a good crucible, which has been heated till it begins to vitrify, can seldom be trusted a second time in the fire.

A crucible should never be introduced, or taken out of the fire by tongs, holding it by one side only, but by such as will embrace it closely on the outside, by having the mouth of the tongs of the curvature of the crucible. When a crucible is very hot in the furnace, the fire should not be suffered to get very low, since the introduction of a great quantity of cold fuel will be liable to break the crucible. Crucibles are much more liable to crack when they have been baked very hard. If they are merely hard enough to bear putting into the fire, and to bear the weight of the materials, it is sufficient.



*Common Air
Furnace.*

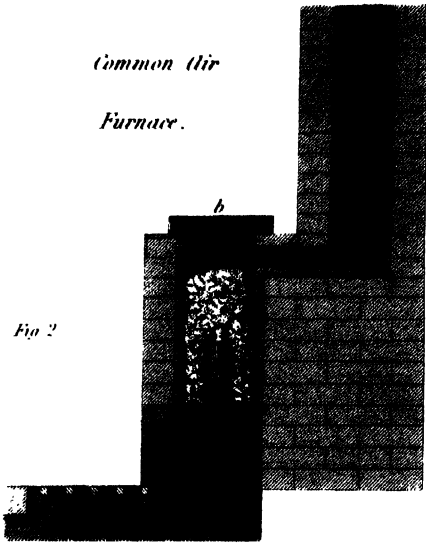


Fig. 2

D^r Black's.

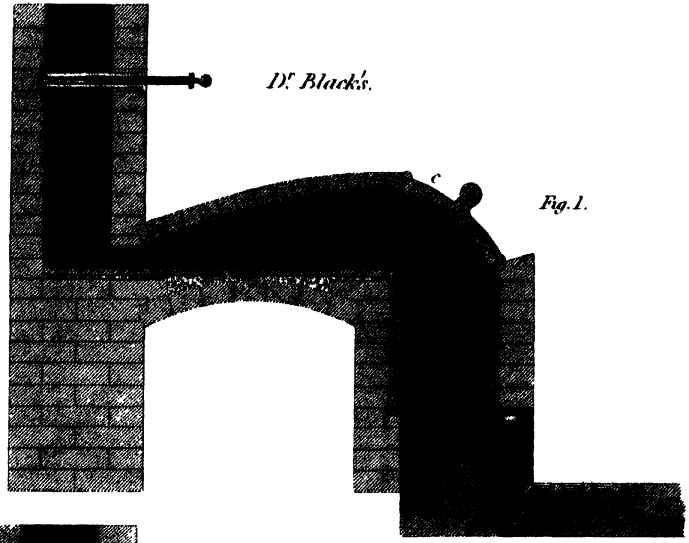


Fig. 1.

M^r Mushet's.

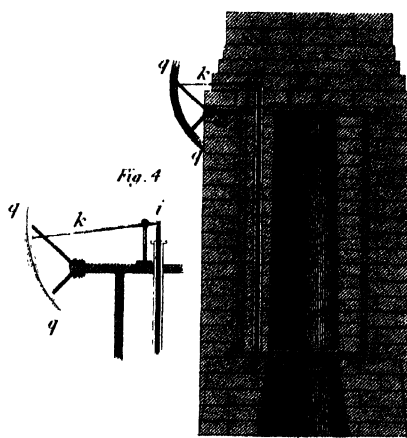


Fig. 4

M^r Knight's.

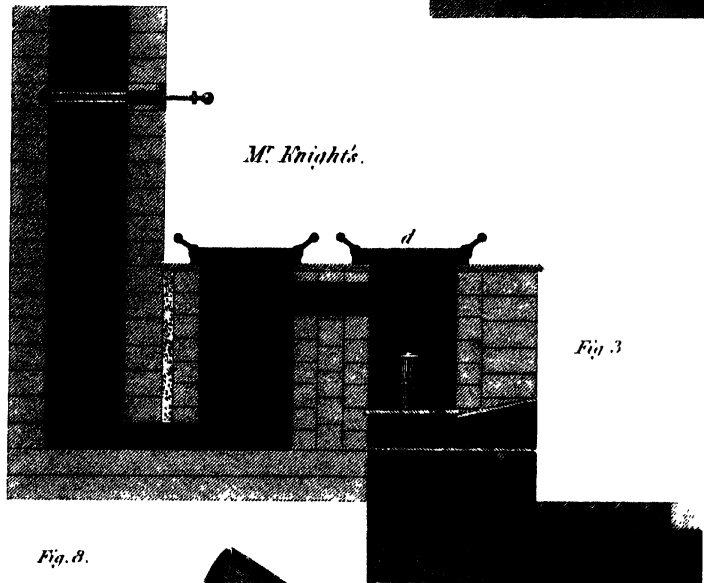


Fig. 3

Portable by D^r Black.

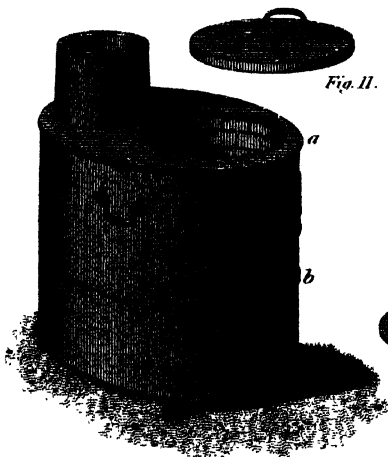


Fig. 6.

Fig. 8.

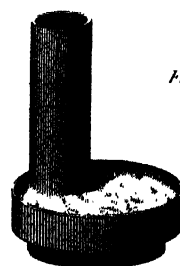


Fig. 7.

Fig. 10.

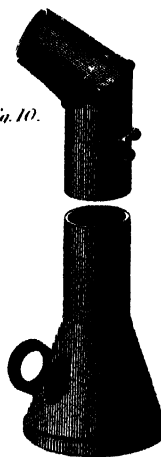


Fig. 9.

Knight's Portable.

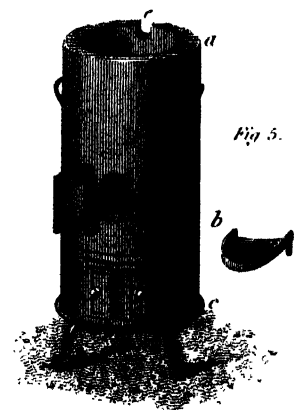
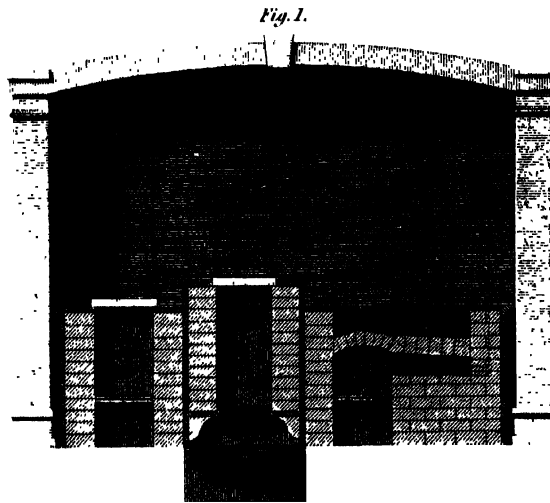
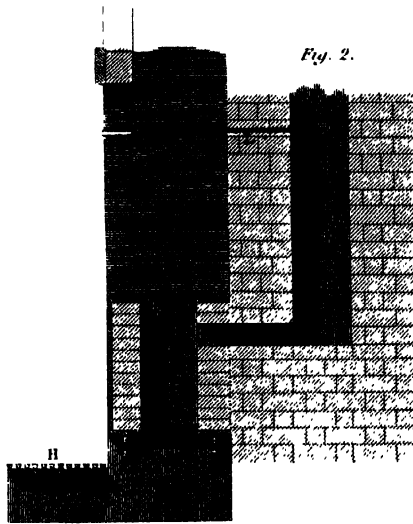


Fig. 5.

FURNACES.

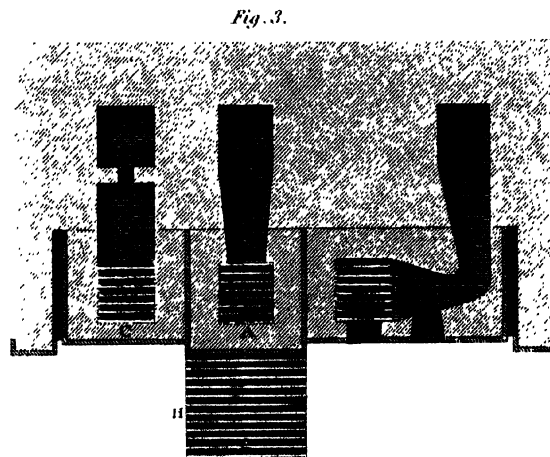
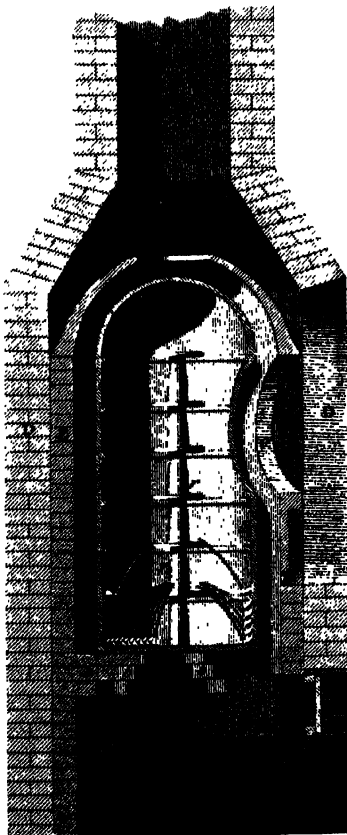
PLATE III

Furnaces used by M^r Mushet for his experiments on Iron & Steel.

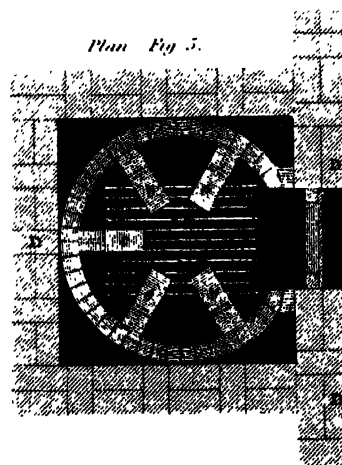


Section of the Tobacco pipe makers Furnace.

Fig. 1



Plan Fig. 5.



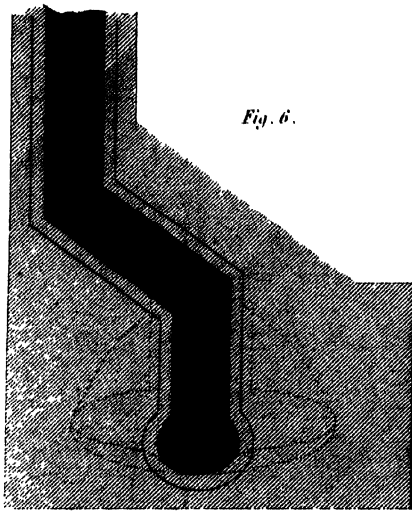


Fig. 6.

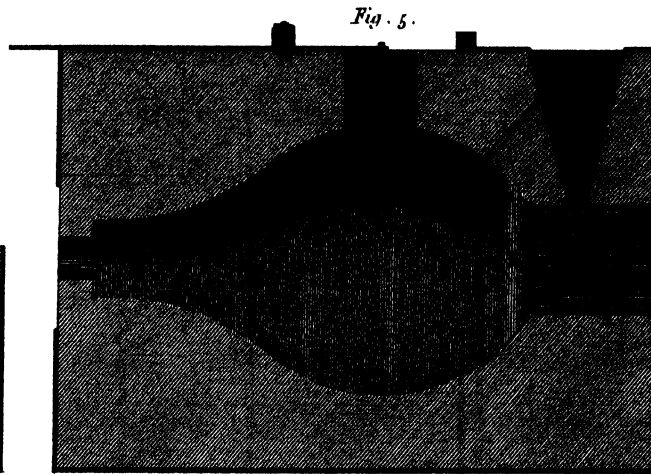


Fig. 5.

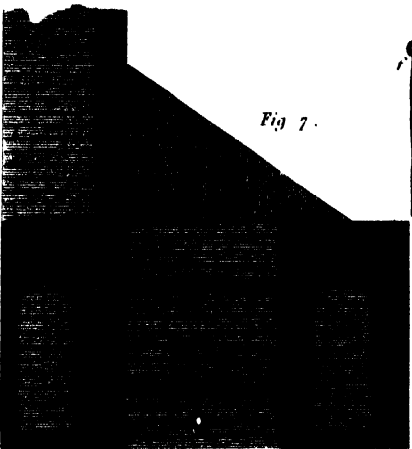


Fig. 7.

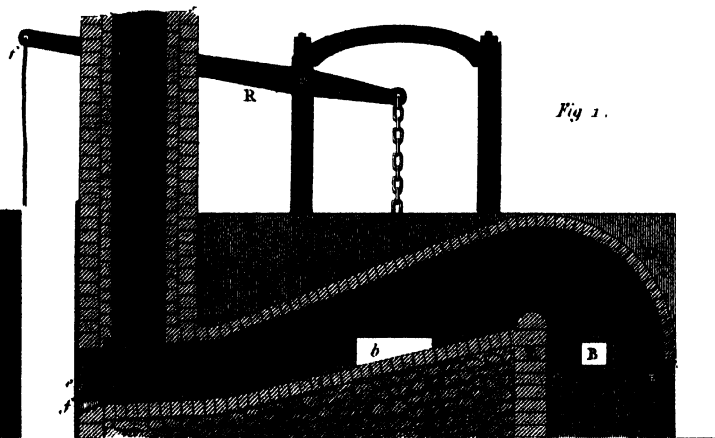


Fig. 1.

Feet
16 14 12 10 8 6 4 2 0 0 2 4 6 8 10 12 14 16

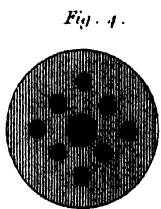


Fig. 4.

Fig. 5.

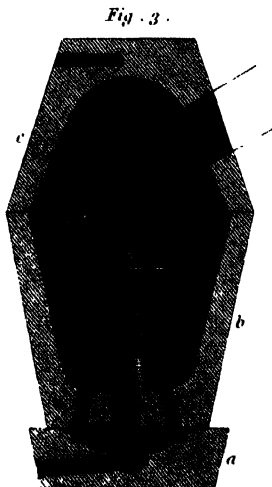


Fig. 3.

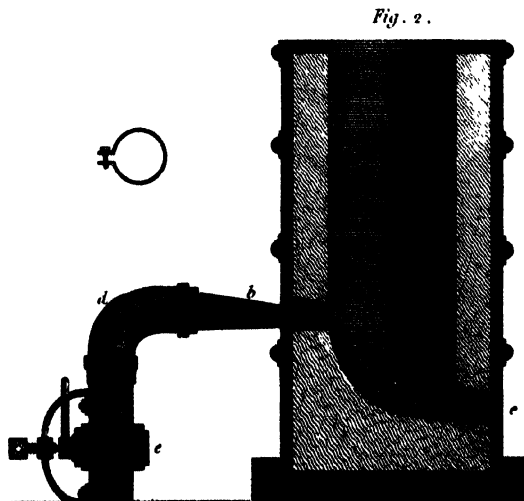
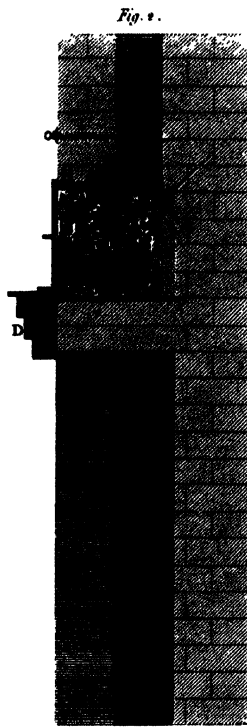


Fig. 2.

Feet

FURNACE.

PLATE V.



Furnace for Enamelling Watch Dial Plates.

2 feet

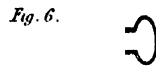
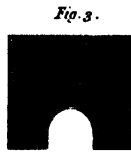
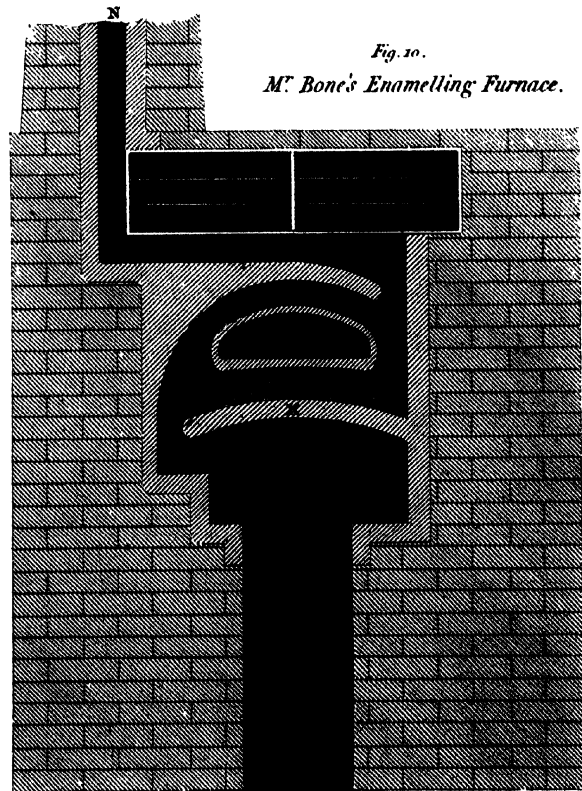
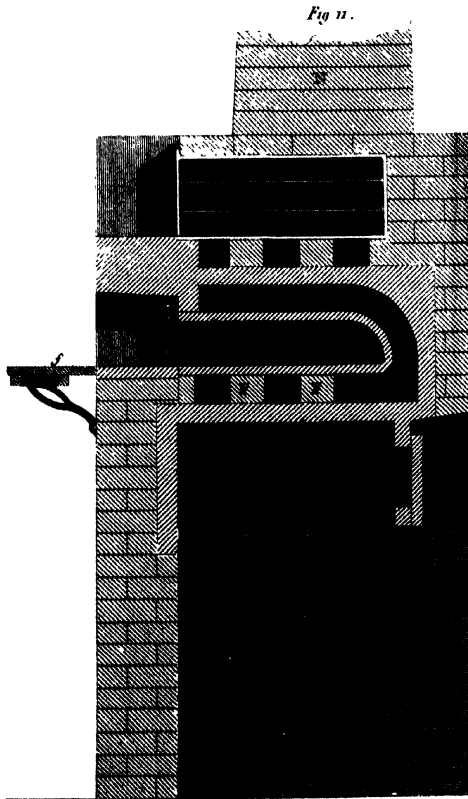


Fig 7

Fig. 8.

Fig. 9.



Scale of Feet.

Fustian

FUSTIAN, in *Commerce*, a kind of cotton stuff, which seems, as it were, quilted, or whaled on one side.

Manege derives the word from *fustanum*, which in the corrupt Latin writers is used in the same sense, and is supposed to be formed from *fustis*, on account of the tree whereon the cotton grows. Bochart derives it from *fustat*, which, in Arabic, signifies the ancient city of Memphis, where cotton is produced in great abundance. Right fustians should be made altogether of cotton thread, both woof and warp.

FUSTIAN, in the *Manufacture of Cloth*, is a species of coarse thick twilled cotton, and is generally dyed of an olive, leaden, or other dark colour previously to its being used. Besides the common fustian which is known by the name of pillow (probably pilaw) fustian, this manufacture, which is chiefly carried on in Lancashire, and the west riding of Yorkshire, comprehends the cotton stuffs known by the names corduroy, velverett, velvetcen, thickfett, and the other

thick fabrics used for men's wearing apparel. The commonest kind of fustian is merely a twill of four, and sometimes five leaves of a very close stout fabric, and is very narrow, seldom exceeding 17 or 18 inches in breadth. It is cut from the loom in half pieces or ends as they are usually called, and after undergoing the subsequent operations of dyeing, dressing, and folding is ready for the market. The end or half piece is generally from 30 to 40 yards.

The draught and cording of common fustian is very simple, being generally a regular or unbroken twell of four or five leaves. Below are specimens of a few different kinds selected from those most general in Lancashire.

The number of leaves of heddles are directed by the lines across the paper, and the cording by the cyphers at the left hand corners, those which raise every leaf being distinguished by the cyphers, and those which sink them left blank, as more especially explained in the article DRAUGHT and Cording.

No. 1.—Pillow Fustian.

o				4		5		1	§		o				3	1
	o			3		6		2	§		o	o			5	
		o		6		2		3	§		o		o	o		2
			o	5		1		4	§				o		6	4
2	4	3	1								4	6	2	3	1	
															5	

No. 2.—Plain Velveret.

Of the above each contains four leaves of heddles or healds; that represented by No. 1. is wrought by four treddles, and that which is distinguished by No. 2. by five; the succession of inserting the threads of warp into the heddles will be discovered by the figures between the lines and the order in which the treddles are to be successively pressed down by the figures below.

No. 3.—Double Jean.

○			○		1	§		○					8
○		○			2	§		○	○	○			6 4
	○	○			3	§				○			5 2
○		○			4	§		○		○	○		7 3 1
4	2	3	1					4	6	2	3	1	
										5		7	

No. 4.—Plain Thickfett.

These, like the former, are wrought with leaves. No. 3. requires four, and No. 4. five treddles. The succession of inserting the threads of warp, and of working the treddles, are marked by the respective numbers between and under the lines, as in the former example. Both are fabrics of cloth in very general use and estimation as low priced articles.

No. 5.—Beil Thickfett.

○			○	○		3	1	§		○				5	3	1	
			○			5		§		○	○				4	2	
	○						2	§		○		○	○		4	2	
		○	○			6	4	§				○			5	3	1
6	4	2	3	1						6	4	2	3	1			
															5		

No. 6.—Velvet Tuft.

These are further specimens of what may be, and is, executed with four leaves, and in both examples five treddles are used. With two other specimens we shall conclude our examples of this description of work, and shall then add a very few specimens of the more extensive kinds.

No. 7.—Cord and Velveret.

o					3	1		3	1	§		o			o	o		5	3	1
	o	o			5		7	5		§		o	o					4	2	
		o		o	o	6		8		2	§							9	7	
			o			4	2	6	4	§		o	o					10	8	6
4		2	3	1								5	4	3	2	1				

No. 8.—Thickfett Cord.

In these the succession of drawing and working are marked like the former. The next are examples of patterns wrought with six leaves. No. 9. has eight, and No. 10. five heddles.

No. 9.—Double Corduroy.

			o		o		o		1	§				o	o		1
		o			o				2	§			o		o		2
	o	o	o	o	o				3	§		o		o	o		3
			o		o				4	§		o	o		o	o	4
		o				o			5	§		o		o		o	5
		o		o					6	§		o		o			6
2	4	6	8	10	12	3	1					4	2	5	3	1	
						7	5					8	6	11	9	7	
						11	9					1	2	10			

No. 10.—Genoa Thickfett.

Miscellaneous Remarks.—In the manufacture of cloth it is difficult to fix upon any generic term for a variety of articles which, however, bear a very near analogy to each other, and are only distinguishable either by a difference in the material of which they consist, or some small variation in the process of manufacture. In this article the word fustian has been used as the generic term, and examples have been given of the most common fabrics of the fanciful varieties of this article. Dr. Johnson contents himself with describing fustian merely as a kind of cotton cloth, which although probably very just, conveys no impression whatever to the mind, excepting, that in its raw state it is a vegetable substance, found in most of the tropical climates, and that when manufactured it serves as a covering for the human body, or for some other domestic purpose.

The examples, short as the article is, will be found to contain an abstract of most of the articles known by the various names of fustian, jean, corduroy, thickset, valeret, velveteen, &c. in the cotton manufacture: of plaiding, blanketing, kerseymere, plum serge, &c. in the woollen, and of satin, &c. in the silk. Of velvet there are properly only two kinds, that with a plain and that with a tweeled, or, as it is here called, a Geneva ground or back. When the material is silk, it is called velvet, when cotton, velveteen, and this is the sole difference. In the same way a common tweeled cloth, when composed of silk, is called satin, when of cotton, fustian or jean, of woollen, plaiding, serge or kerseymere, and in the linen is distinguished by a variety of names according to the quality or fineness, or the place where the article is manufactured. It would tend greatly to simplify an analysis of the various manufactures of cloth, were a general nomenclature introduced, as has been so successfully done, in the more comprehensive and important science of chemistry, and the universal usefulness of the art, as embracing a variety of articles of necessity to the poor, and of ornamental luxury to the rich, would render the attempt very desirable in every respect. But while the knowledge of the art continues to be confined to operative mechanics and to manufacturers, little disposed to study simplicity or arrange and classify ideas, this is rather to be wished for than expected. In all the fanciful branches which form the subject of this article, the cloth undergoes a variety of processes after coming out of the weaver's hands. Of these, the first is cutting the flushed warp to raise the pile as it is called. This is performed on a flat table with a sharp pointed knife. It is necessary in this to be careful that the knife may only

cut the pile without injuring the back or fabric. I am not aware (says the writer of this article) that any attempt has ever been made to render this either more safe or speedy by the aid of any kind of machinery. It is said, indeed, that in the manufacture of Wilton carpets and hearth rugs, (which are merely worsted velvets,) grooved wires are introduced and cut out in the loom by the weaver, the groove in the wire serving as a guide for the knife, to prevent it from injuring the fabric of the cloth. The next operation is that of dyeing, which depending entirely on the chemical processes necessary to give the greatest possible brilliancy and durability of colour, to the material of which the cloth is composed, forms no part of this article. With little variation in the mechanical part, many kinds of cloth, differing widely in the material and equally so in the texture, are made: but the variety is boundless.

FUSTIAN, in *Criticism*, a word used to express bombast. See BOMBAST and FRIGID.

FUSTIC, OLD, as it is called in this country, (the *bois jaune* of the French,) is the wood of a large tree, the *Morus tinctoria*, which grows abundantly in many parts of the West Indies and the American continent. It is of a sulphur colour, pregnant with colouring matter, which is much more durable than any of the other yellow dyes, so that when applied without a mordant, the dye is considerably durable, but still more so when used with the same mordants, as weld or quercitron. The decoction of fustic in water, when strong, has a deep and somewhat dull red yellow, and by dilution becomes orange-yellow. Acids produce in it only a slight precipitate, which alkalies redissolve, rendering the liquor red. Fustic, though valuable on account of the durability of its colour, is seldom used for the pure yellows, as the colour given by it is dull and muddy. It is chiefly used in compound colours, as in forming green with a Saxon-blue basis; or in producing, with a mixed mordant of alum and iron-liquor, an infinite variety of drab and olive dyes, in which case the dullness of its colour is of no consequence. It is chiefly used in general dyeing, and seldom in printing. It goes much farther than weld.

Young fustic, the *fustet* of the French dyers, *Rhus catinus*, or Venice sumach, is a shrub growing in Italy, and the south of France, which gives a fine greenish yellow without any permanence, so that it is never used alone, but merely as an accessory colour to heighten cochineal and other dyes, and occasion their approach to yellow.

Gage

GAGE, in *Carpentry* and *Joinery*, is an instrument for drawing a line on one of the faces of a piece of stuff parallel to another, in order to reduce the stuff to a breadth or thickness.

Its chief use is for gaging of tenons true, to fit into mortises; and for gaging stuff of an equal thickness.

It is made of an oval piece of wood, fitted upon a square stick, to slide up and down stiffly thereon, and with a tooth at the end of a staff, to score, to strike a line upon the staff at any distance, according to the distance of the oval from it.

GAGE, in the *Sea Language*. When one ship is to windward of another, she is said to have the *weather gage* of her.

The seamen also call trying how much water a ship draws *gaging*, or rather *gauging* of her; and it is done thus: They drive a nail into a pike, near the end, and then put down this pike by the rudder, till the nail catch hold under it; for then, as many feet as the pike is under water is the ship's gage, or depth of water she draws.

GAGE, among *Letter-founders*, is a piece of box, or other hard wood, variously notched; which is used to adjust the dimensions, slopes, &c. of the different sorts of letters. There are several kinds of these gages. See **FOUNDERY**.

GAGE, in *Pneumatics*, is of various sorts, according to the purposes to which it is applied. Thus.

GAGE of the Air-pump. The principle upon which the gage of the air-pump is constructed is very obvious; we shall here briefly describe those that are in common use, and refer to the article **AIR-PUMP** for the mode of their application. The "short barometer gage" is merely the lower part of a barometer or a tube about eight or nine inches in length, filled with mercury, and immersed with its aperture into a small quantity of mercury contained in a glass-vessel, which forms the cistern. This gage is either placed under the receiver upon the principal plate of the pump, or it is placed under a separate small receiver, upon a small auxiliary plate, which is annexed to some air-pumps for this purpose. As this gage is not equal to a whole barometer, it will not shew the very small degree of rarefaction; but its indications will commence when about three-quarters of the air have been removed from the receiver, that is, when the air has been rarefied till its remaining elasticity is not able to support that column of mercury. This gage has a scale of inches and parts of an inch affixed to the tube, which shews the precise altitude of the mercury in it. The "long barometer gage" is a tube of about thirty-three inches in length, open at both ends, having its lower end immersed in a cistern of quicksilver, which is fixed on the pedestal, or lower part of the frame of the pump; the tube itself reaching from that place to the height of the plate. The upper aperture of the tube communicates, by means of a brass tube, with the inside of the pump. This is, in reality, an empty barometer, which is filled with quicksilver, by withdrawing the air from it through its upper aperture; and if the pump could produce a perfect vacuum, the mercury in this long gage would rise as high as it does in the common barometer; but as the pump cannot exhaust so far, therefore the difference of altitude between the mercury of the long gage, and that of a common barometer, shews the

quantity of air that remains in the receiver. This difference of altitude is indicated by a scale of inches and parts of inches, which is always affixed to the long barometer gage. As the altitude of the mercury in a common barometer is to its contemporaneous altitude in this gage, so is the whole quantity of air which was in the receiver before the rarefaction to that quantity which has been drawn out of it. The "syphon-gage" differs from the short barometer gage merely in this circumstance; that instead of terminating in a little cistern, in this gage the tube is bent and rises upwards with its aperture, which by means of a brass tube is made to communicate with the inside of the pump; so that the ascending leg of the tube performs the office of a cistern: hence, in rarefying the air, the mercury descends from the closed end of the tube, and rises into the ascending leg; and consequently the altitude of it in one leg above its altitude in the other leg, which is in reality the cistern, shews the degree of rarefaction, and this altitude is denoted by an annexed scale of inches and parts of inches.

The gages above-mentioned evidently indicate the elasticity of the fluid, which remains in the receiver of the pump after a certain degree of rarefaction; and it is immaterial whether that elastic fluid be air, or vapour of water, or other elastic fluid; but there is another gage, which from its shape was called the "pear-gage" by its inventor, Mr. Smeaton, and which shews (not at the actual time, but after the re-admission of air into the receiver) how much air was left in the receiver in the preceding rarefaction. This pear-gage consists of a glass-vessel *A* (*Plate XIV. Pneumatics, fig. 4.*) which has a small projecting orifice *B*, and at the other end it is extended into a tube closed at *D*; the capacity of this tube is the 100th part of the capacity of the whole vessel. This gage is suspended, with its aperture downwards, to the lower end of a slip-wire, or a wire which passes through a collar of leather, within a glass-receiver of the pump, and exactly under it a small cup, containing quicksilver, is placed upon the plate of the pump. When the pump has been worked to the intended degree, the air in the pear-gage is evidently rarefied as much as it is in the receiver. In that state, by lowering the slip wire, the pear-gage is let down till its aperture *B* has reached the bottom of the mercury. This done, the external air is admitted into the receiver; but it cannot be admitted into the pear-gage, because the aperture *B* of that gage is now immersed in the quicksilver; but the pressure of the atmosphere on the surface of the quicksilver forces that fluid into the pear-gage, and fills it up to a certain degree *E*; then the upper part *D E* of the gage will contain all the air or vapour which occupied the whole cavity of the gage during the rarefaction. Annexed to the upper part *D E* of the gage is a divided scale, which shews what part of the capacity of the whole gage is filled with air, and of course it manifests the degree to which the rarefaction of the air had been carried. *E. G.* If we find that the part *D E* of the gage, which is filled with air above the quicksilver, is the 500th part of the whole, we may conclude, that the air in the receiver had been rarefied 500 times, &c. But between the indications of this and of the preceding gages, there

GAGE

will be a very considerable difference. When the receiver contains no other fluid besides air, then the pear-gage and the other gages indicate the same degree of rarefaction; but if the receiver contain the vapour of water or of other liquor, then the pear-gage will indicate a much greater degree of rarefaction than the other gages; because the vapour which has elasticity sufficient to supply the place of air in the receiver, on the re-admission of air, is condensed into a space much smaller than the same quantity of rarefied air can be condensed into; so that the pear-gage shews the quantity of air alone which had been left in the receiver; whereas the other gages shew the quantity of elastic fluid which is actually remaining in the receiver.

The extraordinary powers of exhaustion in Mr. Smeaton's air-pump, as they are indicated by his pear-gage, have been considered with peculiar attention by Mr. Nairne, F.R.S. He was led to prosecute a series of experiments on this subject, by observing the remarkable difference between the indications of exhaustion and rarefaction by this gage, and by the common barometer-gage. Having used every possible precaution in preparing his different gages, he nevertheless found, that, when they are put under a receiver, placed on a leather dressed in alum, and soaked in oil and tallow, according to his usual method, and the pump was worked for ten minutes, the quicksilver in the barometer-gage rose to within one tenth of an inch of the height of the quicksilver in the standard barometer, which was at that time at thirty inches, and indicated that the air had been rarefied only about three hundred times; whereas Mr. Smeaton's pear-gage indicated a degree of exhaustion equal to six thousand times; the whole of its cavity, on dipping its open end into the cup of quicksilver, and letting in the air, except a six thousandth part, being filled by the quicksilver. The difference of indications by these two gages was found much more considerable in subsequent experiments. Having an opportunity of repeating some of these experiments before the honourable Henry Cavendish, Mr. Smeaton, and others, in April 1776, Mr. Cavendish accounted for the observed and astonishing difference, by referring to some experiments of his father, lord Charles Cavendish, from which it appeared, that water, whenever the pressure of the atmosphere on it is diminished to a certain degree, is immediately turned into vapour, and reduced as suddenly to water again on restoring the pressure: the degree of pressure varies according to the temperature of the water; for when the heat is 72 of Fahrenheit's scale, it turns into vapour as soon as the pressure is reduced to that of three quarters of an inch of quicksilver, or about one fortieth of the usual pressure of the atmosphere; but when the heat is only 41, the pressure must be reduced to that of a quarter of an inch of quicksilver, or to one hundred and twentieth of the usual pressure, before the water turns into vapour. According to this theory, whenever the air in the receiver is exhausted to the above-mentioned degree, the moisture adhering to the different parts of the machine will be converted into an elastic vapour, and supply the place of the air, which is drawn away by the working of the pump; and the fluid left in the receiver and pear-gage will be chiefly this vapour. When the air is let into the receiver, the vapour within the pear-gage will be reduced to water, and only the real air will remain uncondensed; and therefore this gage only shews how much real air is left in the receiver, and not how much the pressure or spring of the included air is diminished; whereas the barometer-gage shews how much the included fluid is diminished, and that equally, whether it consists of air or vapour. In order to ascertain the truth of this plausible theory, Mr. Nairne proceeded to free every part of his apparatus as much

as possible from any adhering moisture, concluding that by this means he should be able to bring the two gages to an agreement. Instead of placing the receiver on leather, as before, he put it on the pump-plate, made as clean and dry as possible, and applied a cement round its edge to exclude the outward air. When the pump in this state was worked for ten minutes, the barometer-gage indicated a degree of exhaustion nearly equal to six hundred; and, on letting the air into the receiver, the pear-gage indicated a degree of exhaustion little more than six hundred also. In another experiment he put a piece of the oiled leather above mentioned in the receiver, and found, on working the pump, that the barometer-gage indicated a degree of exhaustion of nearly three hundred, but the pear-gage indicated a degree of exhaustion not less than four thousand. But on taking out the piece of leather, and repeating the experiments, the two gages agreed, as before. Having thus concluded, in general, that a considerable quantity of vapour arose from the compound of leather, alum, oil, and tallow, it was his next object to find out from which of these substances the vapour was principally derived. For this purpose he separately and successively included in the receiver two ounces of tallow, the same quantity of oil and alum, and a piece of leather as it comes from the leather-sellers, weighing a hundred grains: from these experiments he found that the elastic vapour, which occasioned so great a difference in the testimony of the gages, arose chiefly from the leather, and very little from the tallow, oil, and alum. In the experiment with the leather, it supplied the place of the exhausted air so fast, that he could not in ten minutes make the barometer-gage indicate a degree of exhaustion of more than a hundred and fifty-nine; whereas that of the pear-gage was a hundred thousand. In order to determine whether the difference in the gages was occasioned by the moisture of the leather, Mr. Nairne repeated the experiment with a piece of fresh leather, weighing a hundred grains. The pear-gage indicated a rarefaction of a hundred thousand, and the leather had lost two grains of its weight; when the same piece of leather was so thoroughly dried by the fire till it would lose no more of its weight, and thus reduced to eighty grains, it gained two grains in the experiment, and the pear-gage exhibited a rarefaction only of two hundred and eighty. The leather was afterwards held in the steam of hot water till it had regained its former moisture and weight, and the degree of exhaustion indicated by the pear-gage was a hundred thousand, and the loss of weight, two grains, as before. In the first of these experiments, the degree of rarefaction indicated by the barometer-gage was a hundred and thirty-four; in the second, two hundred and sixty-eight; and in the third, one hundred and forty-seven. The effect of the vapour arising from small quantities of different fluids, and from other substances containing moisture, was tried in a variety of instances; and having found that the small quantity of moisture which exhaled from the substances under the receiver, prevented the pump from exhausting to a considerable degree, Mr. Nairne suspected that whenever wet leather had been used to connect the receiver with the plate, there must have arisen so great a quantity of vapour as to have prevented the degree of exhaustion from being near so great as in other instances. This led him to another set of experiments, in order to ascertain this fact. Having first placed the receiver on the pump-plate, made clean and dry, with only a little oil poured round the outside edge of it, both gages agreed in indicating a rarefaction of six hundred, as before; but when the receiver was set on leather that had been soaked for two days in water, the rarefaction indicated by the barometer-gage

was uniformly fifty-one in three different trials; but the pear-gage exhibited first sixteen thousand, in the second instance fifteen hundred, and in the third one thousand: when the receiver was placed on a piece of leather, soaked in a mixture of water and spirit of wine, the barometer-gage in three trials always indicated a degree of exhaustion equal to forty-seven; but the pear-gage was unaccountably various; in the first trial being twelve thousand, in the second, eleven hundred and fifty; and in the third, five hundred. By these experiments it sufficiently appears, that the use of leather soaked in water, or in water and spirit of wine, prevents the pump from exhausting to any considerable degree. By two other experiments, in which water was used for softening the leathers of the pistons of a common air-pump, we find that the highest degree of rarefaction that could be procured was thirty-seven, according to the barometer-gage; and thirty-eight according to the pear-gage. Mr. Nairne's last experiment furnishes a very extraordinary evidence of the effect of vapour on the barometer-gage: having put a phial of ether under the receiver, in order to produce artificial cold, and working the pump for half an hour, the degree of exhaustion indicated by the barometer-gage was only sixteen; though the same pump exhausted above four hundred times before the ether was put under the receiver. The degree of cold produced by means of ether, in the exhausted receiver, was 48° , below 0 in Fahrenheit's scale, or 103 below 55 , which was the temperature of the air in the room where the experiment was made. Phil. Transact. vol. lxxvii. part ii. art. 32, page 614, &c.

GAGE of the Barometer, is a contrivance for estimating the exact degree of the rise and fall of the mercury in the Torricellian tube. It is well known, that whilst the mercury rises in the tube, it sinks in the cistern, and *vice versa*; and, as the distance between the divisions graduated on the annexed scale and the surface of the mercury in the cistern is not truly shewn by the numbers on the scale, errors must happen in determining the precise height of the mercury. To remedy this inconvenience, a line is cut upon a round piece of ivory, which is fixed near the cistern: this line is accurately placed at a given distance from the scale; *e. gr.* twenty-seven inches; and a small float of cork, with a cylindrical piece of ivory fixed to its upper surface, on which a line must be cut at the distance of two inches, exactly from the under surface of the cork, is left to play freely on the quicksilver, and the cylinder works in a groove made in the other piece: from this construction it appears, that if these marks are made to coincide, by raising or lowering the screw which acts on the quicksilver, then the divisions on the scale will express the true measure of the distance from the surface.

GAGE of the Condenser, is a glass tube of a particular construction, adapted to the condensing engine, and designed

to shew the exact density and quantity of the air contained at any time in the *condenser*, which see. For this purpose, let *D defc*, Plate XIV. *Pneumatics*, fig. 5. be a small glass tube, about one-tenth of an inch in diameter, open at *D*, but hermetically sealed at *c*; *DE* a larger tube, hermetically sealed at *D*, and containing at that end a quantity of mercury, which takes up two or three inches in length, and covers the open end of the smaller tube; the other end *C*, of the larger tube, is strongly cemented into the brass elbow-piece *OEo* at *C*, fig. 6, so as not to be quite at right angles with *Oo*, but to incline a little downwards, that the mercury at *D* may not run towards *C*, and pass into the condensing glass *GB*. This gage is screwed on at *o*, and the injecting syringe at *O*, a cock being interposed at *O* or *c*, or not used at all, according to the nature of the experiment. Whilst air is injected into the condensing glass, and the large tube of the gage at the same time, the air in the smaller tube, which has no communication with the injected air, must be rarer and weaker, and, therefore, the mercury at *D* will enter the tube, and advance in it, in proportion to the condensation of the air in *GB*. In fig. 5, *d, e, f*, represent three rings of springy wire, at such distances as to shew, by the motion of the mercury in the small tube, when the density of the air is doubled, tripled, or quadrupled; because the air, which at first filled the whole small tube, now takes up only the spaces *cd, ce, ef*; or, in Mr. Hawksbee's style, one, two, or three atmospheres are thrown in.

Another kind of gage may be put within the condensing glass, at the bottom of it, when the use of the preceding gage would be inconvenient. This is a short cylinder of wood, fig. 7, about an inch thick, with a hole through its middle between *a* and *b*, of about $1\frac{1}{2}$ inch in diameter; the outward diameter of the cylinder must be about four inches, so that the cylinder may easily stand within the condensing glass on the plate, supporting its bottom at *B*, fig. 6. There is a hole at *A* of about $\frac{1}{4}$ of an inch in diameter, and $\frac{1}{4}$ of an inch deep, filled with mercury; *acdb* is a small glass tube, open at *a*, but hermetically sealed at *b*, and bent to a right angle at *c*, the middle of the distance between *a* and *b*. When the open end, *a*, is immersed in mercury, and the air on the surface of the mercury condensed, the air in the tube will recede towards the elbow *c*, and the mercury following it, shew to what degree it is condensed. When the mercury is at *c*, then one additional atmosphere bears upon its surface, and two atmospheres, if it be come to *d*; which places are marked by rings of springing brass wire; at *a* and *b*, about an inch of the ends of the tube are bent to a right angle, that the end *b* may go into the wood, whilst the end *a* goes under the surface of the mercury, where it is held by a cork, whilst air is injected into the condensing glass. Desaguliers' Exp. Phil. vol. ii. p. 394, &c.

Gallic Acid

GALLIC ACID. *Acide Gallique*, Fr. *Gallussäure*, *Gallapf-säure*, Germ.—The infusion of nut-galls had long attracted the attention of chemists, and had been the subject of numerous experiments before it was proved to contain a peculiar acid. Dr. Lewis, when engaged in an enquiry on the best method of making ink, found that the precipitate which a solution of galls affords with sulphat of iron is not attracted by the magnet; he likewise observed that the black colour which it imparts to the acid solutions of iron is capable of being destroyed and re-produced by the alternate application of alkalies and acids. The academicians of Dijon went farther; they ascertained that it reddened vegetable blues, dissolved iron, decomposed the alkaline hydro-sulphurets, produced with metallic solutions various coloured precipitates, and, that when distilled, the fluid product had the same properties as the original solution; but it was reserved for Scheele to separate the acid from the substances with which they had examined it, in combination. This he in a great measure effected by the process which he made public in 1780. The acid discovered by the Swedish chemists, when its peculiar nature was determined, acquired, on account of the substance which first afforded it, the name of acid of galls, or gallic acid. But it is not confined alone to nut-galls; a variety of other astringent vegetables are capable of affording it.

The following method of obtaining the acid, is that discovered by Scheele. Make an infusion, by macerating one part of gall-nuts, reduced to a coarse powder, in six parts of cold water. At the end of fifteen days filter the solution, and place it in a large vessel, covered with a sheet of paper, in a warm room. In a short time, a mouldy pellicle will appear on the surface of the liquid, which is to be occasionally broken: as the operation proceeds, the original

astringent taste diminishes, and the acid taste becomes more sensible. At the end of two or three months, the interior of the vessel will be found coated with a brown matter, containing dispersed, shining, granular, crystals. Separate this sediment, and cover it with rectified alcohol; gently heat the mixture, and a solution of the crystallized acid in alcohol will be formed, which, evaporated, affords gallic acid in the form of very fine grains.

Scheele discovered that gallic acid is volatilized by a low degree of heat; and, in distilling nut-galls, he found the acid sublimed and condensed in the receiver. Mr. Deyeux was the first to avail himself of this property, in order to obtain the acid free from the tannin and extractive matter, which it always contains, when prepared in the old way. He gradually heated powdered nut-galls in a large glass retort, till a sublimate arose, which condensed in brilliant white crystalline plates. An increase of heat occasions the decomposition of the acid; and if the operation is long continued an oil distils over that dissolves the acid sublimate, and renders the experiment fruitless. This method, without great precaution, is very liable to fail. Mr. Davy recommends separating previously some of the tannin of the nut-galls, by infusing them, for a short time, in a little water, by which means the production of empyreumatic oil is diminished. The same chemist observes, that it is time to stop the operation, when the crystals formed in the lower part of the retort begin to melt. But, even allowing all these precautions are observed, it appears almost impossible to obtain the acid entirely free from empyreumatic oil, the presence of which is indicated from the very commencement of the operation, by the peculiar aromatic smell that is produced.

A variety of other methods have been proposed for pro-

uring the acid in a state of purity. It will be sufficient to mention briefly those which appear most adequate to the purpose. Mr. Davy's method: Boil carbonat of barytes in an infusion of galls; gradually add dilute sulphuric acid to the bluish-green liquid which is thus produced, till all the barytes is separated: the liquid, on the application of the common tests, appears to be perfectly free from tannin and extractive matter; evaporate it to dryness, and the gallic acid will be obtained. This method is far preferable to the one recommended by Mr. Fiedler, which consists in digesting alumine with a solution of galls, decanting the clear liquor, and separating the crystals of gallic acid, (more probably of super-gallat of alumine,) which are produced by slow evaporation. Mr. Richter's method: Take any quantity of gall-nuts reduced to a fine powder; digest them in cold water; agitate the mixture; pass the liquid through a cloth; add more water to the residual pulp; and separate the water by means of a press: join the liquors, and slowly evaporate them; a brittle dark coloured substance remains. Cover this substance, reduced to a fine powder, with alcohol, and a solution of a pale straw-colour is formed; a second infusion of alcohol acquires but very little colour. Distil the two extracts together in a small glass retort to one-eighth; add water to the residue, and expose it to a gentle heat; evaporate the solution thus formed, and very small white prismatic crystals of gallic acid will appear. By this process, half an ounce of crystals may be procured from a pound of gall-nuts. M. Bouillon La Grange, who has employed it, says, he was never able to obtain acid of the purity described by Mr. Richter. The crystals he procured were always of a light straw-colour; and he found that repeated distillations with alcohol did not render them white, the gallic acid itself being partially decomposed by this treatment. One objection to this method is, that unless the alcohol is highly rectified it dissolves a portion of tannin.

The properties of gallic acid appear, in some measure, to depend on the method employed for its production. The different methods, generally considered, are of two kinds, the dry and the moist. Accordingly, there appear two varieties of gallic acid, that procured by distillation differing considerably from that formed by crystallization, if any credit is to be attached to the observations of M. Bouillon La Grange.

Gallic acid, procured in the moist way, is of a light straw-colour; it has a sharp acid taste, but possesses less astringency than nut-galls; it changes vegetable blues to red. For its solution, it requires 12 parts of cold water, or 14 of boiling; and it imparts to this liquid a light lemon-colour, which becomes black by exposure to the air. Alcohol takes up, when cold, about 1/4th of its weight of this acid; but at a boiling temperature, nearly its own weight. It is soluble in either. Exposed to heat, it readily fuses; it forms just before it begins to sublime a brown viscid fluid; full of air-bubbles; and emits vapours which have an odorous smell. The action of a strong heat partially decomposes it; but to accomplish this completely, it requires, on account of its volatility, to be subjected to repeated distillations, and the products appear to vary according to the intensity of the heat applied. Scheele procured, by distilling it in a glass retort, first, an acid liquor, free from oil; next, part of the acid itself, which, condensed in the liquid, forms and shoots into crystals, as it gradually cools, and a large residue of charcoal. M. Deyeux has found that it is capable of being converted by heat into oxygen and charcoal. From whence he concluded that it differs only from carbonic acid in containing less oxygen; but his reasoning is fallacious, from his not having taken into consideration the acid fluid that is also

produced. On the contrary, M. Bouillon La Grange obtained, by its distillation, an acidulous liquid, charcoal, and much carbonic acid gas, with which was mixed a little carburetted hydrogen gas. The latter gas was so concealed by the former, that it did not appear inflammable till the carbonic acid gas was separated by means of lime-water.

Gallic acid is decomposed and carbonized by strong sulphuric acid; the same effect, most probably, is produced by liquid fluoric acid; nitric acid converts it partly into the malic and oxalic acids; oxymuriatic acid, according to M. Bouillon La Grange, has no action on it; it is soluble in the other acids without decomposition.

With the earths and alkalies it combines, forming salts, denominated gallats, of which very little is known. The alkaline gallats possess a considerable degree of solubility: according to Richter they give black precipitates, with the salts of iron, and precipitate all other metallic solutions. From the observations of Mr. Davy, the alkaline earths appear capable of combining with two different proportions of this acid, an excess of acid rendering the salts very soluble, which before possessed little solubility. Gallic acid precipitates glycine, yttria, and zircon from their acid solutions, and decomposes all the carbonates.

The gallats are decomposed by a strong heat. Some of them have been found to yield acetic acid when distilled with very dilute sulphuric acid.

The action of gallic acid on metallic salts appears to be proportionable to the strength of the affinity which the different metals have for oxygen. The solution of this acid imparts to a solution of gold a dark green colour, and produces a brown precipitate, which is metallic gold. It renders a solution of silver brown, and occasions, with the assistance of a gentle heat, the deposition of a grey powder, which is finely divided silver. The precipitate which it gives with a solution of mercury is orange yellow; with a solution of copper, brown; with a solution of acetat of lead, white; and with bismuth, lemon coloured. It imparts to molybdic acid a dark yellow, without occasioning any precipitate. It appears to have no effect on the salts of platinum, zinc, tin, cobalt, and manganese. When boiled on red oxyd of mercury, the acid itself is decomposed, and running mercury is produced. It suffers the same change when similarly treated with the black oxyd of manganese or oxyd of tin; but these metals, instead of being reduced, are brought only into lower states of oxydation. The most distinguishing property this acid possesses, is that of giving dark-blue coloured precipitates with the oxygenated salts of iron. According to M. Berthollet's views of the subject, it is not absolutely necessary that the iron should be at the maximum of oxydation for this effect to be produced, for he observes that the salts which contain the oxyd at the minimum, though not changed at first by gallic acid, yet become coloured; when the solution confined from air is much diluted with water. He conceives, and M. Richter is of the same opinion, that every thing which weakens the affinity of the sulphuric acid for the oxyd promotes the combination of the gallic acid with the metal in whatever state of oxydation it may be: indeed the latter chemist asserts, that a solution of green sulphat of iron is never coloured by gallic acid, unless tannin be present, which, according to him, attracts the sulphuric acid, and then the gallic acid unites with the oxyd of iron separated. Mr. Proust, from his observations, has been led to a different conclusion. He thinks that iron is incapable of combining with gallic acid, unless highly oxydated; and he thus explains the colour which a mixture of green sulphat of iron and gallic acid acquires by exposure to the air; the blackening of ink after being poured out of close

vessels, and many of the manipulations of dyers who find their profit in this oxydating process carried on in the atmosphere. M. Berthollet indeed admits that gallic acid strikes a deeper colour with the oxygenated salts of iron, than with those which contain less oxygen; but he attributes this effect to the decomposition of the acid itself, and the development of some of its charcoal.

Such are the general properties of gallic acid procured in the moist way. M. Bouillon La Grange has pointed out a few instances in which the acid obtained by sublimation according to the method of Deyeux differs. These differences it will be necessary to mention, they are principally the following. The sublimed acid is less acid to the taste. It gives to metallic solutions precipitates of different colours. Its solution is darkened by oxymuriatic acid. It imparts variable colours to sulphat of iron, and it does not precipitate gelatine. It moreover appears to contain a little essential oil, which by dissolving the acid in water, ether, or a strong solution of pot-ash, separates, becomes sensible to the smell, and is seen swimming on the surface of the fluid.

The nature of gallic acid is not yet satisfactorily determined. The generally received opinion is, that it is a simple acid, but there are some chemists who maintain it to be a compound one; M. Bouillon La Grange has endeavoured to shew that the crystallized acid procured in the moist way is composed of acetic acid, tannin, and extractive, and that the acid obtained by sublimation is merely acetic acid

modified by a peculiar essential oil. His arguments for this opinion are, the difficulty, indeed the impossibility, of obtaining the acid free from these impurities, and the production of acetic acid by the distillation of gall-nuts with water, and also by submitting some of the gallas to the same operation with dilute sulphuric acid. However ingenious this reasoning may be, it is not conclusive. Doubt can be alone banished from the subject, by submitting the theory to the test of experiment; by endeavouring to form gallic acid of either kind by adding to the acetic the substances by which it is supposed to be modified, in the acid in question. It is certain, however, that, like the other vegetable acids, gallic acid is a compound of carbon, hydrogen, and oxygen, and not, as M. Deyeux maintains, of carbon and oxygen alone.

Its uses are few, in its purest state, and these are known alone in the laboratory of the chemist; but in combination with other substances, it is of extensive and important applications in the arts. See the articles **DYEING** and **INK**.

Elemens de Chimie, tom. iii. Crell's Chemical Journal, vol. i. p. 24. Journals of the Royal Institution, vol. i. p. 274. Nicholson's Journal, 8vo. vol. i. p. 458. Phil. Mag. vol. xxiii. p. 74. Annales de Chimie, tom. xvii. Chemical Statics, vol. ii. Annales de Chimie, tom. 60. p. 156.

Gas Light

Gas Light, Apparatus for producing. The light and heat procured by the combustion of carburetted hydrogen gas, is one of those recent inventions which promises to be of the most general utility, though it may be said to be at present in its infancy; the inflammability of the gas, produced from the distillation of pit coal, has long been a fact familiar to chemists, though it is only within these few years that experiments have been made, with a view to determine the best form of an apparatus for producing the gas, at the least expence of fuel for the distillation, and at the same time to separate from it the tar and ammoniacal fluid which are thrown out from the coals with it; and would, if suffered to remain with the gas, cause many inconveniences from their intolerably offensive smell, but may, when separated, be applied to useful purposes.

Mr. Murdoch was probably the first person who put in practice gas lights on an extensive scale; he commenced his experiments on this subject in the year 1792, and in 1798 he applied it for the lighting part of the very extensive manufactory of Messrs. Boulton, Watt, and Co. at Soho near Birmingham, and in 1802, at the time of the Peace, the illumination of the Soho works was made by gas. Since this period, the method has been adopted in many places by different individuals, who, proceeding from their own ideas, naturally introduced various forms of the apparatus, the most perfect of which we propose to describe with drawings, in such a manner as to enable mechanics to construct them, this being the most probable means of their being farther improved, and their advantages more fully established. The carburetted hydrogen gas is produced in the following manner: A quantity of pit coal is introduced, and closed up in an iron retort, disposed in a proper furnace, by which it can be heated so as to throw out the volatile portions of the coals; these are conducted by a pipe into a refrigeratory, where the tar and ammoniacal fluid are deposited; the gas then enters into a gazometer, being in its way passed through wa-

ter to wash and take from it any remaining tar or other impurities which may cause an unpleasant smell. The gazometer is fitted up in the same manner as for other chemical experiments, rising and falling freely in water to regulate the admission of the gas, which is conveyed by pipes from it to the burners or lamps where it is consumed. These are formed in various ways, either a tube ending with a simple orifice, at which the gas issues in a stream; and if once lighted will continue to burn with the most steady and regular light imaginable, as long as the gas is supplied. At other times a number of very minute holes are made in the end of a pipe, which form as many *jets de feu*, and have a very brilliant appearance. This may sometimes be placed in the focus of a parabolic reflector. In cases where the light is required to be thrown to a distance, other burners are constructed upon the same principle as the Argand lamp, forming a cylinder of flame, and admitting a current of air both to the inside and outside.

Fig. 1. of Plate XVII. Miscellany, is a section of an apparatus for producing the gas adopted by Mr. Samuel Clegg of Manchester, and communicated to the Society of Arts in 1808, when they voted Mr. C. a silver medal for the communication. A represents a cast iron retort, in which are put the coals, to be decomposed by the heat of a fire applied beneath it. The retort is situated in a chamber represented by the dark space, in which the flame from the coals placed upon the grate B circulates all round the retort, and escapes by the chimney D; E is the ash-pit beneath the grate; the double thickness of metal beneath the retort denotes a saddle or half cylinder of cast iron, which preserves that part of the retort which is most exposed, and causes it to be heated more uniformly; F is the mouth where the coals are introduced, it has a flaunch and a cover ground together, air tight, and fastened by a screw in the centre, or by one at each side: a is an iron pipe conducting from the retort to a vessel

G, situated beneath the gazometer : in this vessel the tar and other condensible products are separated from the gas, which ascends the pipe *b*. The upper end of this is covered in the manner of a hood by a cylindric vessel *d*, open at bottom, but partially immersed beneath the surface of the water contained in the cistern of the gazometer, and perforated round, near the lower edge, with a number of small holes. The gas displaces the water from the receiver *d*, and escapes through the small holes rising in bubbles through the water, so as to expose a large surface to its action, that it may be washed and purified from any smell. After rising through the water, the gas enters the gazometer **H H**, which is suspended to move up and down by the chains and pulley *e e*, and balance weights *f, f*. In the centre of the gazometer a tube *g* is fixed, having some small holes at its upper end, by which it communicates with the interior of the gazometer. This tube includes another, *h*, fixed perpendicular from the bottom of the cistern, and communicating with others *k*, which convey the gas to the burners. The fixed pipe *b* forms a guide to keep the gazometer always perpendicular ; and the pipe in the centre of the gazometer prevents any gas passing away except it has ascended to the top of that vessel, and is transparent and fit for use. The gazometer is made of iron plate rivetted together, and sustained by a strong hoop at top and another at bottom. Each hoop has radial bars which support the tube *g* in the centre, and at the same time they strengthen the whole. The gazometer must be painted within and without to preserve it from rusting. Mr. Clegg says, a vessel of this kind, to contain 700 cubic feet of gas, will weigh about 20 cwt.

When the operation commences, the gazometer is sunk down nearly to a level with the surface of the water in the cistern **L L** ; but as the gas enters, it rises up to receive it. It is to be noted, that the balance weights *f, f*, should not be quite so heavy as the gazometer, in order that some pressure may be exerted, to force the gas out of the burners with a proper jet. The gas which issues from the retort enters the receiver **G**, ascends the pipe *b*, into the vessel *d*, from which it displaces the water, and passes out at the small holes as before described, rising through the water into the gazometer, and raising it up : the gas then passes away to the burners. In this manner the process proceeds, until the whole of the volatile products of the coals in the retort is evaporated. The use of the gazometer is, to equalize the emission of the gas which comes from the retort more quickly at some time than others. When this happens, the vessel rises up to receive it, and when the stream from the retort diminishes, the weight of the gazometer expels its contents. When the process is finished, the retort is suffered to cool, and its lid is then removed to replenish it with coal. The caput mortuum, which is found in the retort, is the most excellent coak, and in value returns a considerable portion of the whole expence of fuel when the retort cools. The vessel *d* contains a sufficient quantity of gas to supply any absorption which takes place without raising the water into the retort.

In Mr. Clegg's original apparatus the chains for the balance weight are attached to the top of the gazometer ; and the cistern **L**, for containing the water of the gazometer, is represented as a well sunk in the ground. This method is cheap and simple, though at the same time it is liable to have leaks, which are not easily discovered or accessible to be stopped ; and it requires considerable length of pipes to draw off the matter from the receiver **G** ; whereas in the construction represented in the plate, they are drawn off by the cock at *x*. Of these products we shall speak more in another place.

Fig. 2 and *3* represent one of the gas lamps on the principle of Argand ; the space between the two concentric tubes *a, b*, is supplied with gas by a pipe, *c*, in which is a cock, *d*, to regulate or occasionally intercept the gas. The space between

the two tubes is covered at top with a circular ring, shewn in *fig. 2*, pierced with a number of small holes, at which the gas issues, forming a cylinder of flame, to which a current of air is brought through the internal tube *d*. The air has also passage beneath the glass chimney, *f*, to supply the outside of the flame, which is rendered the most steady and regular imaginable, by the draught caused by the chimney : *g* is a small button affixed to a stem, which slides up and down in the interior tube with sufficient friction to retain its position. The button conveys the current of air rising through the tube in an expanded cone to the inside of the flame, and assists the combustion in a great degree.

The next apparatus for gas lights which we shall describe is by Dr. Stancliffe, as shewn in *fig. 4*. **A** is a vessel of cast-iron, forming the retort, and is set in brick-work in any proper furnace ; **E** is a rim cast in the same piece, inclosing the top of the former, so as to make a deep groove all round in the top of the vessel. In this groove the head, **F**, of the vessel is received ; and to make the fitting airtight, a quantity of fusible alloy is placed in the groove. This melts by the heat of fire, and forms a fluid luting, which prevents the escape of the gas. **G** is a tube leading from the head to the refrigeratory **E F** ; the joining of this tube with this vessel is formed by a joint, on a similar principle to the joining of the head with the retort : *a* is a tube passing through the lid of the vessel, and another, *b*, is fixed concentric to and surrounding the former at a small distance. The space between these is filled with water, and the tube, **G**, which connects with the head, is immersed in the water which forms the joint round the pipe, and by this means the tube, **G G**, and the head, **F**, of the retort, can be removed together to take out the coak and introduce fresh coals. The refrigeratory is made in two divisions **E** and **F**, one above the other ; the tube **G** goes down nearly to the bottom of the lowest division, and the gas bubbles up from the end of it through the water, with which the lower partition is partly filled : it then passes out at the pipe, *d*, to the burners. These must not be of such a number as to consume the gas as fast as the retort produced it ; by this means it will be under a considerable pressure in the vessel, which is found conducive to the separation of the tar, &c. When the gas comes over quickly from the retort, it presses upon the surface of the water, and causes it to ascend through the pipe, *e*, in the partition into the upper chamber, where its weight constantly acts to cause a pressure, and expel the gas at the pipe, *d*, whenever the supply of the retort diminishes ; *f* is another pipe through the partition to allow the escape of the gas, if it forces out the water so low as the bottom of the pipe : the gas which then rises into the upper division gets away by the pipe *g* into the chimney of the funnel. Dr. Stancliffe has recently taken out a patent for the method of luting of the head and joint at **G**, as applied to the distillation of any other matter.

Fig. 5 is an apparatus by Mr. B. Cooke of Birmingham, recently communicated by him to the Society of Arts, and rewarded by them with a silver medal. The pipe **A** leads the gas from the pot or retort, and is fitted, in a manner similar to Dr. Stancliffe's, to a vessel **B B**, called the purifier. This is filled half full of water, and has five partitions, *a, a, a, a, a*, soldered to the lid, and extending beneath the surface of the water ; at the lower edge a number of holes are pierced in the plates through which the gas issues, and rises in bubbles through the water on the opposite side. In this manner it proceeds through all the plates, and is by that means washed and purified most perfectly, the cold water condensing and depositing in the bottom of the vessel the tar and ammoniacal liquor, which can be drawn off by the

cock *b*; *M* is the pipe which conveys the gas away from the end of the purifier, and leads it to the bottom of the tube, *L L*, of the gazometer, which is omitted in the drawing, as it is the same as in Mr. Clegg's apparatus, and furnished with balance weights in the same manner: *N* is the pipe to take the gas away to the burners. Mr. Cooke has placed his connecting pipes, *M* and *N*, inclined, and at the lowest point a short pipe *n*, which is immersed in the water contained in a vessel *m*, so as to prevent the escape of any gas, but at the same time to allow any tar, &c. to drain down the pipe and deposit itself in the water. By this means the tar, which will unavoidably rest in these pipes, is disposed of without danger of clogging or stopping the passage, as might happen in course of years, though the quantity was ever so minute. Mr. Cooke recommends for dwelling-houses, where the gas is required to be particularly free from smell, that it should be passed through a second purifier containing lime water, which will render it perfectly pure.

In any of these apparatuses, it is essential that the water used for washing and purifying the gas should be changed for fresh as soon as it becomes dirty; and unless this is done the gas will not be perfectly purified by washing, but retain an unpleasant smell after it. The tar which deposits itself at the bottom of the vessel, in the consistence of treacle or thick oil, is first drawn off by the cock: for that purpose this substance is found very useful, and in many points forms a substitute for the vegetable tar. By boiling it, the volatile parts are evaporated, and it becomes pitch. If the evaporation is performed in a retort, the matter which comes over is a spirit, which, according to Mr. Cooke, may be used instead of that kind of turpentine, known by the term tar spirit, in painting and japanning; and he gives particular directions for the manner of performing this distillation in the 28th vol. of the Transactions of the Society of Arts. The residuum left in the retort is pitch; or, if further boiled, makes asphaltum, or a substance which is equally applicable, for the various arts in which it is employed.

It is proper that we should here notice Mr. Winfor's process for procuring gas, coak, and many other products, from pit-coal: but as this process has not been wholly made public, our notice must be short. A company has been established for the purpose of carrying into execution his invention, and has applied to parliament for powers to act as a corporate body. Those who form this body, propose to erect apparatuses, in convenient situations, and convey the gas by pipes along the streets of a town, for the purpose of lighting them, as well as the houses. Experiments were made of this plan by lighting one side of Pall Mall, in London, which appeared to answer well; and the company's house has been constantly lighted and heated by gas since the first establishment.

Mr. Winfor, at the opening of the business, gave lectures and experiments on the gas, though the manner of procur-

ing and purifying it he kept a secret: he exhibited the mode of conducting it through the house, and a number of elegant devices for chandeliers, &c. by which it was consumed. Among these he proposed long flexible tubes suspended from the ceiling of the room, and at the end communicating with a burner, which was designed with much taste, being a cupid holding a torch in one hand, and grasping the tube, in the same manner, as a rope in the other. This figure was to be suspended by hooks in any convenient part of the room where light was required, and might be carried into any closet or other place within the limits of the length of the tube. He shewed also by experiments, that the flame of the gas was not liable to be extinguished by wind or rain, that it produced no smoke, and was not so dangerous as the light of lamps or candles, as it could not produce sparks.

A pamphlet has been recently published by Mr. Van Voorst, stating the evidence taken before the committee of the house of commons appointed upon the bill, for the incorporation of the Gas Light Company. This gentleman states the products of a London chaldron of coals, treated in Mr. Winfor's process, to be, 1st, light by the combustion of the gas equal to 2,100 parish lamps burning 11 hours: 2d, $1\frac{1}{2}$ chaldron of coak by admeasurement: 3d, 60lbs. of pitch: 4th, three gallons of essential oil: and, 5th, 18 gallons of ammoniacal liquor; and he enters into a calculation of the pecuniary profits; but this we forbear to detail, as being entirely dependent upon the local situation and value of the coals and their products. This statement is collected chiefly from the evidence of Mr. Accum. The bill was rejected by parliament; but we understand, by the above pamphlet, that the company intend to prosecute their undertaking without a charter of incorporation.

Mr. Murdoch made a communication in 1808 to the Royal Society on the subject of gas light, and was complimented with count Rumford's medal for the same. He gives the results of the process as conducted in the cotton mills of Messrs. Phillips and Lee, at Manchester, who have a very large apparatus constructed by Mr. M. at the Soho works. The gas lights are equal to 2500 mould candles of six in the pound, each candle consuming 175 grains of tallow per hour. The number of burners are 271 Argands, and 633 cockspurs, so called from having three jets diverging from each other. These require an hourly supply of 1250 cubic feet of gas to produce, which requires seven cwt. of cannel coal in the retort, and about one third of that quantity of good common coal to heat the retort. The cannel coal in the retort produces nearly $4\frac{1}{2}$ cwt. of good coak, and $4\frac{1}{2}$ ale gallons of tar. The ammoniacal liquor was not regarded, as it has not yet been applied to any manufacture, so as to be demanded in large quantities; though a paper by Mr. Wm. Cox will be found in Mr. Van Voorst's pamphlet, shewing the advantages of the ammonia as applied for manure, and some other experiments on its use in dyeing. See FLAME.

Gauge

GAUGE, in *Engineering*, sometimes signifies the same with weir: a gauged bar is an upper gate, or over-fall to a weir. See Smeaton's Reports, vol. i. p. 62.

GAUGE-line, a line on the common gauging-rod, whose description and use see under the article GAUGING.

GAUGE-point of a solid measure is the diameter of a circle, whose area is equal to the solid content of the same measure.

Thus the solidity of a wine gallon being 231 cubic inches: if you conceive a circle to contain so many inches, the diameter of it will be 17.15: and that will be the gauge-point of wine measure.

And an ale-gallon containing 282 cubic inches; by the same rule, the gauge-point for ale-measure will be found to be 19.15: and after the same manner may the gauge-point of any other measure be determined.

Hence we deduce, that when the diameter of a cylinder in inches is equal to the gauge-point in any measure (given likewise in inches) every inch in length thereof will contain an integer of the same measure. In a cylinder, whose diameter is 17.15 inches, every inch in height contains one entire gallon in wine-measure; and in another, whose diameter is 19.15, every inch in length contains only one ale-gallon.

GAUGE-weir, in *Engineering*, is a weir or over-fall, out of some reservoir, or pound of a canal, calculated to discharge a given quantity of water daily, for the supply of mills, or some other canal. See CANAL.

GAUGER, an officer appointed by the king to gauge, i. e. to examine or measure, all casks, tuns, pipes, barrels, hogheads of beer, wine, oil, &c. and to give them a mark of allowance (which is a circle burnt with an iron) before they be sold in any place within the extent of this office.

Of this officer and his office we have many statutes; thus, by 27 Edw. III. c. 8. all wines, &c. imported, are to be gauged by the king's gaugers or their deputies; by 31 Edw. III. c. 5. selling wine before gauged, incurs forfeiture, or the value: and by 23 H. VI. c. 15. the gauge penny is to be paid gaugers on gauging wines. The 31 Eliz. ordains that beer, &c. imported shall be gauged by the master and wardens of the Coopers' company: see 12 Car. II. c. 4. The wardens of the Coopers shall attend to gauge vessels upon request. 23 Hen. VIII. c. 4. Gaugers may take samples not exceeding half a pint, 32 Geo. II. c. 29. See EXCISE.

GAUGING, the art or act of measuring the capacities or contents of all kinds of vessels, and deter-

mining the quantity of fluids or other matters contained therein.

Gauging is the art of reducing the unknown capacity of vessels of divers forms, cubical, parallelepipedal, cylindrical, spheroidal, conical, &c. to some known cubic measure; and of computing, for instance, how many gallons, quarts, pints, or the like, of any liquor, *e. gr.* ale, beer, wine, brandy, &c. are contained therein.

Gauging is a branch of stereometry.

The principal vessels that come under its operation are pipes, barrels, rundlets, and other casks; also backs, coolers, vats, &c.

The solid content of cubical, parallelepipedal, and prismatical vessels, is easily found in cubic inches, or the like, by multiplying the area of the base by the perpendicular altitude.

And for cylindrical vessels, the same is found by multiplying the area of the circular base by the perpendicular altitude, as before.

Casks of the usual form of hogheads, kilderkins, &c. may be considered as segments of a spheroid cut off by two planes perpendicular to the axis: which brings them to Oughtred's theorem for measuring ale and wine casks, which is thus: add twice the area of the circle at the bung to the area of the circle of the head; multiply the sum by one-third of the length of the cask, the product is the content of the vessel, in cubic inches. But for accuracy, Dr. Wallis, Mr. Caswell, &c. think, that most of our casks had better be considered as frustums of parabolic spindles, which are less than the frustums of spheroids of the same base and height, and give the capacity of vessels nearer the truth than either Oughtred's method, which supposes them spheroids; or than that of multiplying the circles of the bung and head into half the length of the cask, which supposes them parabolic conoids: or than that of Clavius, &c. who takes them for two truncated cones: which is farthest off of all.

The common rule for all wine or ale casks is to take the diameters at the bung, and at the head, by which you may find the area of the circle there; then taking two-thirds of the area of the circle at the bung, and one-third of the area of the circle at the head, and adding them together into one sum, this sum, multiplied by the internal length of the cask, gives the content in solid inches; which are converted into gallons, by dividing by 282 for ale, and by 231 for wine gallons.

The readiest method for common use is to reduce the cask

to a cylinder of equal contents; and this is done by considering what is called the variety of the cask. Suppose a cylinder inscribed in a cask, and another circumscribed about it, there will be a cylindrical space included between the superficies of the two cylinders, whose diameter or thickness is equal to the difference between the bung and head diameters of the cask; the curvature of the staves of the cask takes in a certain proportion of the cylindrical space, which is greater or less, as the curvatures bend, or bulging of the staves is greater or less; and this determines what is called the variety; and it will be the first variety, if the cask bulges very much; second variety, if less, and so on: it is, therefore, evident, that the diameter of the inscribed circle may be increased so as to take in a portion of the interjacent cylindrical space equal to that taken in by the curvature of the staves of the cask; and then the cask and increased cylinder will be equal in content. The diameter of the inscribed cylinder is the head diameter of the cask; the thickness of the cylindrical space is equal to the difference between the bung and head diameters. The only difficulty, therefore, lies in determining what portion of this difference must be added to the head diameter of the cask, in order to obtain the diameter of the mean cylinder, or the cylinder of equal content. Now experience shews, that if 7-10ths of the difference between the head and bung diameters of any cask be added to the head diameter, the cylinder whose diameter is equal to this sum, and whose length is equal to that of the cask, will contain as much or more than that cask, though the staves have the greatest degree of curvature that is ever given to them. And as the difference between the bung and head-diameters of casks is seldom very great, the contents of a cask whose staves are quite straight from bung to head, or of a cask made up of two equal frustums of two equal cones, will generally be nearly equal to the contents of a cylinder, whose diameter is equal to the sum of the head diameter of the cask, and a little more than half the difference between the bung and head diameters, and whose length is equal to the length of the cask. Therefore, all the varieties of which casks are capable, lie between 5-10ths and 7-10ths of the difference between the bung and head diameters; and the gauger has only to take such a part of this difference (always between 5-10ths and 7-10ths) as his judgment and experience inform him to be most suitable to the curvature of the cask; and this, added to the head diameter, gives the diameter of the mean cylinder.

It may not be amiss to note here, that the difference between the bung and head diameters may be very great, and yet the cask have no bulging at all, for the bulging is the bend or curvature of the half-stave, between the bung and the head.

Mathematicians give us abstruse theorems, for computing the contents of casks, upon the supposed resemblance between the curvature of the cask and that of an ellipsis, parabola, or hyperbola; but they may be as much mistaken in judging of the curvature, as an experienced gauger between 5-10ths and 7-10ths: for after all, the contents of casks cannot be determined to a mathematical exactness; because the forms of casks do not exactly answer any mathematical figures. The business of gauging is at best but guess-work; but it is such a way of guessing, as comes near enough the truth for the common purposes of life.

Hence we may add such decimal multipliers, for the difference between bung and head diameters as have been found by experience to be the truest, and best suited to the several varieties or curvatures of casks.

First variety, or staves very much bulging, .7 or .695
Second variety, or staves not so much curved, .65 or .63

Third variety, or staves still less curved, .6 or .56

Fourth variety, or staves almost straight, .55 or .51

The following rule will serve for gauging casks by the pen: take the difference of the bung and head diameters of any cask, and multiply that difference by the number which stands against the name of the cask given in the table, add the product to the head diameter; and the sum will be the diameter of a cylinder, which, being of the same length with the given cask, will contain as much; square the diameter thus found, and multiply that square by the length, and divide the product by 359 for beer gallons, and 294 for wine.

The multipliers for a cask, which is taken for varieties:

The middle frustum	{	1. Of a spheroid	.7	greatest bulge.
		2. Of a parab. spindle	.63	next less.
		3. Two conoids	.56	next less to that.
		4. Two cones	.51	next less to that.

Example.—Let a cask be taken as the middle frustum of a spheroid, the bung diameter of which is 32 inches, the head 26, and length 50 inches; what is the content in beer and wine gallons? $32 - 26 \times .7 = 4.2$. To which add 26, and we shall have 30.2 for the mean diameter; and $30.2^2 = 912.04$, which multiplied by the length 50 will give 45602; and $\frac{45602}{359} = 127$ beer gallons; and $\frac{45602}{294} = 155.1$ wine gal-

lons. The contents of other casks may be found in the same manner by using the proper multipliers. See Everard's *SLIDING rule*.

For the ready computation of the contents of vessels, or of any solids in the measures of use in Great Britain, we shall here insert the following rules taken from a Treatise of Practical Geometry, published at Edinburgh in 1745, 8vo. Vide pag. 137. seq.

1. To find the content of a cylindric vessel in English wine gallons, the diameter of the base and altitude of the vessel being given in inches and decimals of an inch: square the number of inches in the diameter of the vessel; multiply this square by the number of inches in the height, then multiply this product by the decimal fraction 0.0034, and you will have the contents of the vessel in gallons, and decimals of a gallon. For example, let the diameter be = D = 51.2 inches, the height = H = 62.3 inches, then will the content be $D D H \times 0.0034 = 51.2 \times 51.2 \times 62.3 \times 0.0034 = 555.27342$ wine gallons.

2. Supposing the English ale gallon to contain 282 cubical inches, the content of a cylindric vessel is computed in such gallons, by multiplying the square of the diameter of the vessel by its height as before, and their product by the decimal fraction 0.0027851, that is, the solid content in gallons will be $D D H \times 0.0027851$.

3. If the Scotch pint contains 103.4 cubical inches, the content of such a vessel in Scotch pints, will be $D D H \times 0.0076$.

4. Supposing the Winchester bushel to contain 2178 cubic inches, the content of a cylindric vessel is computed in those bushels, by multiplying the square of the diameter of the vessel by the height, and the product by the decimal fraction 0.0003606. But the legal Winchester bushel containing only 2150.42 solid inches, the content of a cylindric vessel is computed in such bushels, by multiplying the square of the diameter by the height, and their product by the decimal 0.0003652. Or the content will be $D D H \times 0.0003652$. See *BUSHEL*.

5. Supposing the Scotch wheat firiot to contain 214 Scotch pints, or about 2197 cubical inches, the contents of a cylindric vessel in such firlots will be $D D H \times 0.000358$.

And if the beer firiot contain 31 Scotch pints, the contents of such a vessel in beer firlots will be $DDH \times 0.000245$. See FIRLOT.

6°. It is to be observed, that when the section of the vessel is not a circle, but an ellipse, the product of the greatest diameter by the least is to be substituted in these rules, for the square of the diameter.

7°. To compute the content of a vessel, which may be considered as the frustum of a cone in any of those measures. Let A represent the number of inches in the diameter of the greater base, B the number of inches in the diameter of the lesser base. Compute the square of A, the product of A by B, and the square of B. Take the third part of the sum of all these, and substitute it in the preceding rules for the square of the diameter, and proceed in all respects as before. Thus for example, the content in wine gallons will be $AA + AB + BB \times \frac{1}{3} H \times 0.0034$. Or thus: To the square of half the sum of A and B add one-third of the square of half their difference; and substitute this sum in the preceding rules for the square of the diameter of the base of the vessel. For the square of $\frac{1}{2} A + \frac{1}{2} B$ added to $\frac{1}{3}$ of the square of $\frac{1}{2} A - \frac{1}{2} B$ gives $\frac{1}{4} AA + \frac{1}{2} AB + \frac{1}{4} BB + \frac{1}{12} AA - \frac{1}{6} AB + \frac{1}{12} BB = \frac{1}{4} AA + \frac{1}{2} AB + \frac{1}{4} BB$.

8°. When the vessel is a frustum of a parabolic conoid, measure the diameter of the section at the middle of the height of the frustum: and the content will be the same as of a cylinder of this diameter, of the same height with the vessel.

9°. When a vessel is a frustum of a sphere, if you measure the diameter of the section at the middle of the height of the frustum, then compute the content of a cylinder of this diameter, and of the same height with the vessel, and from this subtract $\frac{1}{4}$ of the content of a cylinder of the same height, on a base, the diameter of which is equal to that height; the remainder will give the content of the vessel. That is, if D represent the diameter of the middle section, and H the height of the frustum, you are to substitute $DD - \frac{1}{4} HH$ for the square of the diameter of the cylindric vessel in the first six rules.

10°. When the vessel is a frustum of a spheroid, if the bases are equal, the content is readily found by the rule given from Oughtred. In other cases, let the axis of the solid be to the conjugate axis, as n to 1; let D be the diameter of the middle section of the frustum, H the height or length of the frustum, and substitute in the first six rules $DD - \frac{HH}{3nn}$ for the square of the diameter of the vessel.

11°. When the vessel is a hyperbolic conoid, let the axis of the solid be to the conjugate axis as n to 1, D the diameter of the section at the middle of the frustum H, the height or length, compute $DD + \frac{HH}{3nn}$, and substitute this sum for the square of the diameter of the cylindric vessel in the first six rules.

12°. In general, it is usual to measure any round vessel, distinguishing it into several frustums, and taking the diameter of the section at the middle of each frustum; thence to compute the content of each, as if it was a cylinder of the mean diameter; and to give their sum as the content of the vessel. From the total content computed in this manner they subtract successively the numbers which express the circular areas that correspond to those mean diameters, each as often as there are inches in the altitude of the frustum to which it belongs, beginning with the uppermost; and in

this manner calculate a table for the vessel, by which it readily appears how much liquor is at any time contained in it, by taking either the dry, or the wet inches; having regard to the inclination, or drip of the vessel, if it has any.

This method of computing the content of a frustum from the diameter of the section at the middle of its height, is exact in that case only when it is a portion of a parabolic conoid; but in such vessels as are in common use the error is not considerable. When the vessel is a portion of a cone or hyperbolic conoid, the content by this method is found less than the truth; but when it is a portion of a sphere or a spheroid, the content computed in this manner exceeds the truth. The difference or error is always the same in different parts of the same, or similar vessels, when the altitude of the frustum is given. And when the altitudes are different, the error is in the triplicate ratio of the altitude. If exactness be required, the error in measuring the frustum of a conical vessel, in this manner, is $\frac{1}{4}$ th of the content of a cone, similar to the vessel, of an altitude equal to the height of the frustum. In a sphere it is $\frac{1}{4}$ of a cylinder, of a diameter and height equal to the frustum. In the spheroid and hyperbolic conoid, it is the same as in a cone, generated by the right-angled triangle contained by the two semiaxes of the figure revolving about that side which is the semiaxis of the frustum. These are demonstrated in a treatise of fluxions by Mr. Maclaurin, where those theorems are extended to frustums that are bounded by planes oblique to the axis in all the solids, that are generated by any conic section revolving about either axis. Vide p. 25. and 715.

In the usual method of computing a table for a vessel, by subtracting from the whole content the number that expresses the uppermost area, as often as there are inches in the uppermost frustum, and afterwards the numbers for the other areas successively, it is obvious that the contents assigned by the table, when a few of the uppermost inches are dry, are stated a little too high, if the vessel stands on its lesser base, but too low when it stands on its greater base; because, when one inch is dry, for example, it is not the area at the middle of the uppermost frustum, but rather the area at the middle of the uppermost inch, that ought to be subtracted from the total content, in order to find the content in this case.

But gauging, as now practised, is chiefly done by means of instruments called *gauging-rods*, or *rules*, which do the business at once, and answer the question without so much calculation; which is no inconsiderable addition, both to the ease and dispatch of the work. This instrumental way of gauging, therefore, we shall here chiefly insist upon.

Dr. Hutton in his "Mensuration" has given rules for computing the contents of the various frustums of solids, which bear resemblance to the several varieties or forms of different casks. Rules adapted to these forms will be found under the denominations of the several solids to which they belong in this Cyclopædia; and they occur in most books, professedly written on the subject of Gauging. We shall here subjoin one general rule, extracted from the above-cited treatise, (p. 592) which may be easily applied to the cases that occur.

General Rule.

Add into one sum 39 times the square of the bung diameter,
25 times the square of the head diameter,
and
26 times the product of those diameters.
Multiply the sum by the length of the cask, and the product by the number .00034; then this last product divided by 9

Gazometer

GAZOMETER, GASOMETER, or *Gas-holder*, are names given to certain instruments or vessels formed as reservoirs for large quantities of gas, to which are added suitable conveniences for receiving and applying the same, and for measuring the volume. Lavoisier and Laplace were the first to design and execute such an instrument, of which a plate, accompanied with a description, was given in the *Elements of Chemistry*, published by the former celebrated philosopher in 1789. This instrument was too complicated and expensive to be of general use. Since that time various have been the alterations and improvements made by succeeding chemists according to the objects they had in view.

Lavoisier's gazometer consisted of a cylindrical copper vessel, open at bottom, and inserted into another larger vessel of the same kind, open at top. The internal vessel is 18 inches in diameter, and 20 inches deep. Around the bottom of this, on its outside, is fixed a border divided into compartments, intended to receive leaden weights, 1, 2, 3, 4, &c. in order to increase the weight of the vessel when considerable pressure is requisite. The top of this vessel is furnished with a tube and stop-cock, forming a communication between the external and internal air, also with a thermometer cemented into it to shew the temperature of the air within. The vessel is supported by a chain from one of the circular ends of a balance beam; and to the other end a scale and weight are suspended as a counterpoise. The external vessel is partly filled with water, and has tubes along the bottom and rising up to communicate with the air in the interior vessel, for the purpose of admitting or discharging it. Some auxiliary glass tubes and a scale of inches are attached to the vessel, to shew the height of the water in the inner and outer vessel, and the difference of the heights, in order to correct for the pressure. This partial description will give an idea of the outline of the structure, which is much too complicated to be exhibited as a model for the present time.

In the 12th vol. of the *Annales de Chimie*, 1792, is given the description of a gazometer by Van Marum: the immediate object of it was to exhibit the composition of water by the slow combustion of hydrogen in a large glass receiver. Two of these gazometers were employed; the one to introduce a stream of hydrogen gas, and the other oxygen. The hydrogen was lighted at the commencement of the experiment by electricity. The apparatus displays ingenuity; but it is complicated and expensive. In the 14th vol. of the same work he gives a simplification of the gazometer as applied to the same purpose; but it is still too complex and too partial in application for general use.

In 1794, Mr. Watt of Birmingham published a pamphlet containing a description of an apparatus for elastic fluids. In this he describes two vessels, the one under the name of *hydraulic bellows*, which is, in fact, the modern gazometer, and the other under the name of *air-holder*. These were illustrated with plates. The hydraulic bellows or gazometer consists of two vessels H and J, *Plate XIV. (Chemistry) fig. 1.* The outer vessel, H, consists of two cylinders placed one within the other, and about half an inch asunder. These cylinders are joined

together at bottom by a circular rim, well soldered to them both; and the inner cylinder is shut at top by a cover also soldered on. This inner cylinder is about two inches shorter than the outer cylinder, and the latter is surmounted by a cup, W W, about $1\frac{1}{2}$ inch deep, and one inch all around more in diameter than the cylinder to which it is attached. The pipe, P Q, passes diametrically across the vessel H; the end, Q, is open, and made so as to be stoped with a cork or cock. From this pipe, P Q, proceeds a pipe V, which passes upwards through the cover of the inner cylinder to which it is soldered, and is open at its upper end. The second vessel, J, of the bellows, is a hollow cylinder of one foot diameter, and eighteen inches long, shut at top, and open at bottom; it is made so as to move up and down easily in the circular interstice between the inner and outer cylinders of the vessel H; and when that interstice is filled with water, as high as the cover of the inner cylinder, if the vessel J is moved up and down, it will act the part of a bellows, drawing in and blowing out air, by the pipes V and P Q. The bellows are made of tinned iron plates japanned, or of tinned copper-plates not japanned.

The air-holder is thus described: Let a cylindrical vessel (*fig. 2.*) be made of strong tin plate; this vessel is to be close at both ends, which are made concave outwards; close to both the bottom and cover, short pipes, U and V, proceed from the side of the vessel; their diameters should be the same as the pipe, P Q, of the bellows. Another pipe, T, passes through the middle of the cover or upper end of the vessel, to which it is well soldered; and reaches within half an inch of the bottom. To guard this vessel from rust it should be japanned both inside and out; and for the greater convenience of japanning it within, it may be made to come asunder at the middle of its height, and when varnished may be cemented together by a mixture of wax and rosin used hot. When this vessel is completed, the upper pipe, U, is to have a short pipe, W, inserted into it, which should also fit the pipe, Q, of the bellows. The lower pipe, V, is then to be corked, and the vessel filled with water by the central pipe T. This vessel is to be placed in an empty tub, the pipe, W, inserted into the pipe, Q, of the bellows, and cemented to it. When the bellows are filled with artificial air, the cork of the lower pipe, V, is to be taken out, and the counterpoise of the bellows is to be lifted up; the water in the air-holder will then run out into the tub, and the air descend from the bellows into the former vessel, which, when full, must have its pipes close corked. To transfer the air from this vessel into a bag or bladder, fix the faucet or mouth-piece of the bag or bladder into the upper pipe U, and if you want a quart or gallon, or other measure of air, pour so much water into the air-holder through the central pipe, and exactly that quantity of air will issue out; then re-cork your vessel until you want more air from it.

In the 5th vol. of the *Philosophical Magazine* 1799, Mr. Pepys describes a new mercurial gazometer. The principle of it is nearly the same as the hydraulic bellows of Mr. Watt. A (*fig. 3.*) is a representation of the bell of the ga-

zometer, made of glass, furnished with a cock at top, and able to contain 34 ounces Troy of distilled water. The divisions of capacity, determined by actual measurement, are marked on the glass with a diamond. B B, are the sections of two cylinders of lignum vitæ (or cast iron), the outward one screwed upon the solid internal one, which is made to project at its lower extremity, and furnished with a male screw, to work into a female screw, with which the lower end of the external cylinder is furnished. The space between these is so adjusted as to be almost filled up by the substance of the glass bell, A, when dropped into it, so that the quantity of mercury necessary to fill up that space is proportionally small. The internal cylinder has a conducting tube up through its axis, the lower end of which is furnished with a female screw answering to the male screw of the cock of the small receiver C. The receiver, C, is of glass, and open at the bottom. When this receiver is used, it is screwed into its place, and rests upon a small cup or cistern of mercury, D, in which the beak of a retort, furnished with a bent glass tube, may be introduced into the receiver. E E E E section of a wooden stand upon which the cylinders of lignum vitæ or cast iron are supported, having an opening through the top to permit the cock of the receiver, C, to be joined to the conducting tube of the internal cylinder B. The cistern, D, is adjusted to its height by means of a rising cylinder in the pedestal F. G is a transfer glass for mixing alkaline gases in vacuo, or other purposes, and when used, is joined to the top of the bell A. H, a glass globe and stop-cock, capable of holding 14 ounces Troy of water, for weighing gases; it receives its gas by being inverted and screwed into the bell A. I, a bladder furnished with a stop-cock, to assist in holding, transferring, or mixing different gases. K, an elastic gum bottle capable of containing 30 ounces of water, for holding the acid gases; when used it is screwed into the top of the transfer G; the bottom cock of the latter being at the same time joined to the bell A, previously charged with the alkaline gas; the cocks being turned, the gases rush together in vacuo. L, a small portable air-pump for exhausting the globe H. M, a double male screw, which fits any part of the apparatus, and on which a valve may be fastened. N, a double female screw. O, a small instrument, of service in collecting spilled mercury, or transferring small quantities of it.

Mr. Davy's Researches, &c. published in 1800, contain an account of a mercurial gazometer by Mr. Clayfield. The peculiarity of this consists, in having the counterpoise to the cylinder suspended by a string which runs in a spiral groove so as to balance the cylinder, whatever its depression in the mercury may be.

The 53d vol. of the *Journal de Physique*, 1801, contains a description of a new gazometer by Victor Michelotti, M. D. of Turin. This instrument, however, can scarcely be recommended for its superiority.

In the 13th vol. of the *Philosophical Magazine*, 1802, Mr. Pepys has described a new gas-holder. The apparatus is in some respects similar to that recommended by Mr. Watt. A small circular cistern is added at top, which is connected with the gas-holder by means of two pipes furnished with cocks. It has also a brass cock on the side, and a glass gage or register tube, shewing the quantity of included gas by the level of the water. The following is a description of the different parts, *fig. 4*. The gas-holder, G, may contain from two to ten gallons. R, the register tube, the ends of which are cemented into two tin sockets by corks at the top and bottom of the gas-holder, into which it opens at both ends; of course the level of the water in the apparatus will always be seen in the tube, and consequently that of the

gas. C, the circular cistern with its two cocks and pipes, marked 1 and 2. Ck a brass cock on the side, with a screw, to which bladders or a blow-pipe may be attached. O, an opening into the gas-holder, in which a pipe is soldered at such an angle, that when all the uppermost cocks are shut, no water can possibly escape. But when a conducting pipe from a retort or other apparatus generating gas, is introduced into this opening, then, as the gas passes up into the gas-holder, an equal quantity of water will be discharged at O into any vessel fit to receive it. Sp, a spout on the side of the cistern to enable the operator to add water, even when the receiver fills its whole area. H, H, handles to lift the gas-holder. Rr, a glass deflagrating receiver, standing in the cistern. A, its adopting cork and cock. S, a watch spring in a slit wire prepared for combustion. The wire passes through a cork. D, a deflagrating disk of iron for sulphur, phosphorus, charcoal, sugar, camphor, &c. B, a blow-pipe with a gum elastic tube, E, capable of joining the cock Ck.

To make use of this apparatus; first fill the gas-holder with water, by closing the opening, O, with a cork, and also the cock, Ck, and keeping the circular cistern full of water, while the cocks 1 and 2 are both open. The air is driven out of the gas-holder through the cock 1, by the water descending into it by the cock 2. When full, the water in the register will be on a level with the top of the gas-holder. Then shut the cocks 1 and 2. You may now remove the cork from the opening, O, which is then prepared to receive the conducting pipe from any apparatus from which the gas is generating. As the gas is delivered the water escapes, and should be caught in any convenient vessel. The register will then shew the quantity received; when full, close the opening, O, with a cork wrapped in leather, which prevents the communication with the atmosphere. It may now be easily removed or conveyed where it is wanted. When it is required to fill a glass receiver, as Rr, with the gas, having previously filled the circular cistern with water, place it in the cistern, put in the adopting cork, A, and with the mouth applied to the cock, exhaust the receiver in which the water will rise till full. Then close the cock, A, and open the two cocks, 1 and 2, and the gas will ascend into the receiver, while the water will take its place in the gas-holder.

In the same volume of the *Magazine* Dr. Warwick suggests a more simple alteration of Mr. Watt's air-holder than the above. It consists in having a rim at the top of Watt's air-holder, so as to admit of a column of water of an inch in depth above the stop cock, soldered to the shorter tube in the top of the air-holder.

In the 23d vol. of *Nicholson's Philosophical Journal*, 1809, Mr. Clegg has given a description of a gazometer or gas-holder for receiving the gas from coals, for the purpose of lighting manufactories, &c. This is on a large scale, so as to hold several hundred cubical feet. The vessel containing the air is made of wrought iron plates, and may be cylindrical, or, which is better, square or oblong, with an internal frame of wood to preserve the figure. This vessel is balanced by a weight in the manner of other gazometers, and is let down into a large well or reservoir of water, like the upper cylinder of Mr. Watt's hydraulic bellows. When in operation, a small head of water presses on the gas, and forces it through the tubes to the lamps, where it is burned. As this apparatus is daily receiving improvement, we shall defer giving a full description of it till the article *Gas-Light*. See also *LIGHT*.

Rules for reducing measures of gases to weights.—In order to reduce any given measure of a gas to weight, the exact

weight of a given volume at a certain pressure and temperature must be previously known. This may be seen in a table under the article GAS. The mean pressure of the atmosphere may be taken at 30 inches of mercury, and the mean temperature at 55° of Fahrenheit. The reduction, on account of pressure, arises from the principle that "the volume of any gas is inversely as the pressure." The reduction, on account of temperature, must be $\frac{1}{4^{\circ}}$ th for every degree of Fahrenheit, between the limits of 32° and 80° . At least this is a sufficient approximation: that is, the volume must be *increased* if the temperature is below 55° , and *diminished* if above 55° , by the fractional part above specified.

Example 1.—Required the weight of 1000 cubic inches of common air in a mercurial gazometer; the mercury within being $2\frac{1}{2}$ inches above the level of that without, the barometer at the same time being 29.5 inches, and the thermometer 62° .

Solution.—Here the real pressure of the gas is $29.5 - .25$ inches = 27. Hence, $30 : 1000 :: 27 : 900$ = the

volume of gas reduced to 30 inches of pressure. Again, $62^{\circ} - 55^{\circ} = 7^{\circ}$, and $\frac{7}{4}$ of 900 = 157.5, which being taken from 900, leaves 742.5 cubic inches of gas at the common pressure and temperature. But 100 cubic inches weigh 31 grains; whence $742.5 \times 31 = 23017.5$ grains, as required.

Example 2.—Required the weight of 1000 cubic inches of common air in a water gazometer; the water within being 3 inches below that without, the barometer at the same time being 29.8, and the thermometer 38° .

Solution.—Here the real pressure of the gas is $29.8 +$ the pressure of 3 inches of water; but 3 inches of water = $\frac{1}{17.8}$ inches of mercury = .22 inch. Whence the pressure = 30.02. And $30 : 1000 :: 30.02 : 1000.7$, the volume of gas reduced to 30 inches of pressure. Again, $55^{\circ} - 38^{\circ} = 17^{\circ}$, and $\frac{17}{4}$ of 1000.7 = 425.2, which being added to 1000.7, gives 1425.9 cubic inches of gas at the common pressure and temperature = 44203 grains.

Gilbert

GILBERT, JOHN, the son of Mr. Thomas Gilbert, a gentleman possessing an estate of about 300*l.* a year, was born in the year 1724. His eldest brother had a liberal education, with a view to the bar, and became afterwards a member of parliament for Newcastle and Litchfield; but the subject of this article had only such instruction as the obscure village of Farley, in the neighbourhood of his father's house, could afford. At the age of twelve or thirteen years, he was bound apprentice to Mr. Bolton, father of the well-known and justly celebrated Matthew Bolton, of Soho, near Birmingham; between whom and Mr. Gilbert an intimacy subsisted, as long as the latter lived. At the age of 19 he lost his father; and as he died possessed of extensive lime-works, they required attention. Accordingly Mr. Gilbert, in order to undertake the superintendence of them, quitted his connection with Mr. Bolton, who very reluctantly parted with him, and devoted himself to the management of his own family concerns. Notwithstanding the disadvantages under which Mr. G. had laboured in early life, he possessed talents, which, matured by age and experience, could not fail of recommending him to notice. But the most remarkable circumstance in the history of this ingenious person, and that indeed which has induced us to give a brief account of him, was his introduction to the duke of Bridgewater, at the time when he was projecting improvements of his collieries, in the neighbourhood of Manchester. Mr. Gilbert's brother was then steward to the duke; and desired him to inspect and examine his Grace's collieries at Worsley. After viewing the works, it immediately occurred to him, that if the coals on that part of the duke's estate could be brought to market in such a populous town as Manchester, and for the supply of the numerous works in its vicinity, the colliery, which, in the state it was at the time of his inspection, yielded little profit, would become extremely valuable. It is said, that he secluded himself altogether from company for two days, at the Bull inn at Manchester, to consider how this might be done by water-carriage, as that by land was very expensive, and, on account of the badness of the roads, very inconvenient, and almost impracticable. Having digested his scheme, he communicated it to the duke, who was no less struck with the proposition suggested by Mr. G. than the projector himself. Accordingly the work was soon after began. Mr. G.'s name has seldom occurred in connection with this very important and lucrative under-

taking; and as he preceded Mr. Brindley in this business, of which we have ample and satisfactory evidence, we thought that justice required a candid and impartial statement of the case. Mr. G. was so fortunate, in the prosecution of this work, as to find lime upon the duke's estate, which must otherwise have been brought by land from Buxton, at the distance of near 30 miles; and in a work of this great extent, this was no inconsiderable saving. The tunnel was entirely executed, as well as planned, by Mr. G.; who, being acquainted with Mr. Brindley as a neighbour, and knowing him to be a very ingenious and excellent mill-wright, engaged his assistance in the conduct and completion of this arduous undertaking, and introduced him to the duke for this purpose. The duke was so well satisfied with his agent and projector, that at first they lived together for two or three months in the year, and for several of the last years of Mr. Gilbert's life, he spent half his time with him. In June, 1757, he removed with his family to Worsley, that he might, with greater convenience, attend the prosecution of the business he had undertaken. As a farther evidence of the duke's regard for Mr. G. we may here add, that he gave his son, who was educated for the church, the second best preferment at his disposal, to the amount of about 1200*l.* per annum. We might mention many other concerns in which Mr. G. was engaged, and in which he had an opportunity of manifesting his skill and judgment, in the conduct of canals, mines, and other improvements relating to rural economy. We shall merely add, that he is said to have been the first person who suggested the use of gun-powder in obtaining rock-salt. Mr. G. was probably so modest and unassuming, that he did not, during his life-time, lay claim to the honour which belonged to him, with respect to the duke of Bridgewater's canals and collieries; and we have introduced his name into the Cyclopædia, in order to do him justice, without meaning to detract from the merit of his coadjutor and successor, Mr. Brindley, to whom we have already paid ample and deserved respect under his biographical article. Mr. Gilbert's general character commanded the esteem of all who knew him; and his death, even after a prolonged life of about 73 years, which happened at Worsley, on the 4th of August, 1797, was, without doubt, regretted by his friends, and especially by the noble duke, who was in the house at the time.

Gilding

GILDING, or GUILDING, the art, or act, of spreading or covering certain substances with gold, either in leaf or powder, or in amalgam with quicksilver. See an account of these preparations of gold under GOLD.

The art of gilding was not unknown among the ancients, though it never arrived among them at the perfection to which the moderns have carried it. For this purpose the gold was beat into plates, with which the walls of apartments, dishes, and other vessels were covered. In early ages these plates were thick, so that this mode of gilding was very expensive. (See the process employed for gilding, in this manner, the horns of the ram brought by Nestor, as an offering to Minerva, in Homer's *Odyssey*, l. iii. v. 492.) In process of time, however, the expence was much lessened, because the art was discovered of making these plates thinner, and of laying them on with a size.

Pliny assures us, that the first gilding seen at Rome was after the destruction of Carthage, under the censorship of Lucius Mummius, when they began to gild the ceilings of their temples and palaces; the Capitol being the first place on which this enrichment was bestowed. But he adds, that luxury advanced on them so hastily, that in a little time you might see all, even private and poor persons, gild the very walls, vaults, &c. of their houses. "When we cover our houses with gold," says Seneca, (*Epist.* 115.) "what else do we than rejoice in deception? for we know, that coarse

wood is concealed under that gold." We need not doubt but that they had the same method with us, of beating gold, and reducing it into leaves; though, it should seem, they did not carry it to the same height; if it be true, which Pliny relates, that they only made seven hundred and fifty leaves, four fingers square, of a whole ounce. Indeed, he adds, that they could make more; that the thickest were called *bractea Prænestina*, on account of a statue of the goddess Fortune at Præneste, gilt with such leaves; and that those of the thinner sort were called *bractea questoria*.

The modern gilders also make use of gold leaves of divers thicknesses; but there are some so fine, that a thousand do not weigh above four or five drachms. The thickest leaves are used for gilding on iron, and other metals; and the thinnest on wood. But we have another advantage above the ancients, in the manner of using and applying the gold: the secret of painting in oil, discovered of late ages, furnishes us with means of gilding works that shall endure all the injuries of time and weather, which to the ancients was impracticable. They had no way to lay the gold on bodies that would not endure the fire but with whites of eggs, or size; neither of which will endure the water: so that they could only gild such places as were sheltered from the moisture of the weather.

The Greeks called the composition on which they applied their gilding on wood, *leucophæum*, or *leucophorum*;

GILDING

which is described as a sort of glutinous compound earth, serving, in all probability, to make the gold stick, and bear polishing. But as to the particulars of this earth, its colour, ingredients, &c. the antiquaries and naturalists are not agreed.

There are several methods of gilding in use among us : viz. *gilding on an oily size* ; *gilding on a water size* ; *gilding by the fire*, which is peculiar to metals ; *gilding of books*, &c.

We may distinguish, in general, two kinds of gilding, one with, and the other without, the application of heat. The first method is practised on those substances, such as wood, paper, leather, silk, lacquered and japanned ware, &c. which would be injured, and even destroyed at the temperature requisite for the other sort of gilding, which is employed on substances that are not liable to alteration by exposure to a moderate heat, such as metals, and sometimes glass and porcelain.

There are two methods of gilding on wood, viz. oil-gilding, and burnished gilding.

GILDING in oil, or an oily size, is performed by cementing the gold to the ground by means of fat oil. Linseed oil may be prepared for this purpose, by putting such a quantity of it into a broad vessel as may cover the bottom about an inch deep, and adding to it as much water as will rise six inches or more above the bottom. Let the vessel be exposed to the sun and rain, and the contents be occasionally stirred for five or six weeks, till the oil appear of the consistence of treacle. Then separate the oil from the water, and place it in a long bottle, or separating-funnel, used by the chemists, in such heat as will render it perfectly fluid ; pour off the clear part, and strain the remainder through a funnel, and the whole will be fit for use. The water helps to clear and bleach the oil, and improve it in other respects.

In order to prepare the wood for gilding, it must first be covered or primed with two or three coatings of boiled linseed oil and white lead, in order to fill up the pores, and conceal the irregularities of the surface, occasioned by the veins in the wood. If greater nicety and perfection in the work be required, the wood should be first rubbed with fish-skin, and then with Dutch rushes.

When the priming is dry, the next operation is that of sizing the work, or laying upon it, by means of a brush, or a large pencil, a thin coat of gold size ; care being taken that the brush or pencil be made to pass into all the cavities and projecting parts, if the subject be carved. This gold size is prepared by grinding calcined red ochre with a due proportion of the fat, or thickest drying oil that can be procured, (the older the better) ; and this size, in order to fit it for working more freely, is to be mixed, previously to its being used, with a small quantity of oil of turpentine, till it acquires a proper consistence. Sometimes the work is sized with fat oil, and the japanner's gold size (see *GOLD SIZE*), ground also with ochre. If a high degree of perfection be required, the work should be sized a second time, and some add a third sizing, before the gold is laid on. In order to ascertain its fitness for this purpose, it is touched with the finger ; and if it feel somewhat adhesive or clammy, or, as the gilders call it, "tacky," but not so as to be brought off by the finger, it is in a fit state for gilding. But if it be so clammy as to daub, or come off on being touched, it is not sufficiently dry ; or, if it has no clamminess or sticking quality, it is too dry, and must be sized over again before it is gilt. When the gold size is good, it will be sufficiently dry in about twelve hours for the application of the gold. In this

process, when the surface is sufficiently large and plain to contain them, the gold leaves may be laid on entire, either by means of a squirrel's tail, or immediately from the paper which originally contained them, which last method, practised by those who have acquired the necessary dexterity, is the simplest and most expeditious, as well as the best, for the perfection of the work. The leaves, being laid on the proper parts of the work, must be settled to the ground, by gently compressing those, which seem to want it, with the squirrel's tail on a cotton ball ; and if any part of the gold has flown off, or has been displaced, so as to leave any spot uncovered, a piece of another leaf, of a corresponding size and figure, must be laid upon it. When the parts are too small to admit of laying on whole leaves, or when vacancies are left, after laying on whole leaves, which require to be covered with the slips or fragments of leaves, those that are to be used are turned from the paper upon a cushion. (See *GILDING Cushion* and *CUSHION*.) They are then cut into slips, of a proper size, by a blunt pallet-knife (see *GILDING Knife*) ; and each slip is taken up on the point of a fine brush, or by an instrument called the "tip," (see *GILDING Tip*), which, being moistened by breathing upon it, will take up the leaves, or any fragments of them from the cushion. When these are thus applied to the parts of the work that were to be covered, they are gently pressed down by the cotton ball, till they lie every where evenly upon the ground ; and the gold will immediately adhere to the sticky surface of the size. Where the work is very hollow, and small pieces are wanted to cover parts that lie deep, they may be taken up, by the tip already mentioned, or the point of a fitch pencil, first breathed upon, and thus conveyed to, and settled in, their proper places. The whole of the work, being thus covered, should be suffered to remain till it be dry, and it may then be brushed over by a camel's hair pencil, or soft hog's hair brush, in order to clear away any loose particles of the gold leaf. If, after brushing, any defective parts appear, such parts must be again sized ; and treated as before. The squirrel's tail used in gilding is cut short, and sometimes spread in the fan-fashion, by means of a piece of wood formed like a pencil-stick, but broad at both ends, and split to receive the tail ; but it will equally serve in its own form, when the hair is cut to a proper length. The cotton should also be formed into a ball, by tying it up in a piece of fine linen rag ; for if it be used without the rag, the fibres adhere to the gold size, and embarrass the work.

This sort of gilding is chiefly used for domes, and the roofs of churches, courts, banqueting-houses, &c. and for figures of plaster, lead, &c. that are to stand exposed to the weather.

This oil-gilding is the most simple and easy, least expensive, and most durable, as it will not be readily injured when exposed to the open air ; and it may be also cleaned with a little warm water and a soft brush ; but, as it cannot be burnished, it wants the high lustre which is produced by the method we shall next describe.

GILDING, Burnished, or in Distemper, or on Water-size, is that kind of gilding which is generally used for picture frames, mouldings, stucco, and such wooden works as are sheltered from the weather, and not subject to dampness. In order to prepare the wood for this sort of gilding, those parts that admit of it should be first well rubbed with fish-skin, and then with Dutch rushes. It should then be carefully covered with strong size, made of shreds, &c. of white leather, such as that used by glovers, or clippings of parchment boiled in water, in the proportion of about a pound of

the shreds or clippings, to fix quarts of water, to the consistence of a jelly, and then strained through flannel while hot. When this coating is dry, eight or ten more must be applied, consisting of the same size, mixed with fine plaster of Paris, or washed chalk, or powdered whiting; which mixture must be made by melting the size, and throwing the whiting, &c. gradually into it, stirring them well together, that they may be thoroughly incorporated. This is laid on with a stiff brush, and oftener or seldomer repeated, according to the nature of the work; for pieces of sculpture, seven or eight layers suffice: for flat, or smooth works, they use ten or twelve. In the latter case they are applied by drawing the brush or pencil over the work: in the former, by dabbing it smartly on, that the size may enter all the dents of the carving.

After the last coat is laid on, and before it be quite dry, a brush pencil, dipped in water, should be passed over the whole, to smooth it, and take away any inequalities that may have been formed; and when it is dry, the parts that admit of it should be again brushed over till they are perfectly even. The work should then be repaired, by freeing all the cavities from the priming: after which a water polish should be given to the parts designed to be burnished, by rubbing them gently with a fine linen rag moistened with water.

When the whole work is become quite dry, a moderately thick layer must be applied, composed of size and bole, or yellow ochre. Doffie, in the *Handmaid to the Arts*, gives the following recipe for the simplest compositions, used as the proper cement or gilding size in this kind of gilding: "Take any quantity of bole armeniac, and add some water to it, that it may soak till it grow soft. Levigate it then on the stone, but not with more water than will prevent its being of a stiff consistence, and add to it a little purified suet or tallow scraped; and grind them together. When this is wanted for use, dilute it to the consistence of cream, by parchment or gloves' size, mixed with double its quantity of water, and made warm. Some melt the suet or tallow, and mix it previously with five or six times its weight of chalk before it is put to the bole, to facilitate their commixture, to which in this wet state they are somewhat repugnant. It is also sometimes practised to put soap suds to the bole; which will contribute to its uniting with the tallow." (See *GOLD SIZE*.) Let this composition be diluted with warm size mixed with two-thirds of water, and let it be spread with a brush over the whole of the work, and then suffered to dry; and then let the same mixture be applied in the same manner, at least once more. After the last coat, it should be rubbed in the parts to be burnished with a soft cloth, till it be perfectly even. Some add a little vermilion to the gilding size, and others colour the work, if carved, before it be laid on, with yellow and the gloves' size; to which a little vermilion, or red lead, should be added. This last method is designed to give the appearance of gilding to the deeper and obscure parts of the carving, where the gold cannot, or is not thought necessary to be laid on. But this practice is much disused; and instead of it such parts of the work are coloured after gilding; which operation is called "Matting."

The work being thus prepared should be set in a position somewhat declining from the operator; who, having at hand a cup of clean water, and some hair pencils, moistens a part of the work, and then applies the gold leaf to the part so moistened in the manner already directed under the article *OIL-GILDING*, till it be completely covered, or till it be too dry to take the gold. This will immediately adhere on being pressed with the cotton ball. The operator proceeds

to moisten the next part of the work, and apply the gold as before, repeating the operation till the whole is completed. If, in examining the work, any parts should appear to need being repaired, they should be moistened as before, and covered with the gold; but care should be taken that no part be missed in the first operation, as it is not so easily mended as in oil-gilding: nor should any drops of water be suffered to fall on the perfect part of the gilding, as the gold is very apt to turn black in this state. The work being thus far gilt, when dry, and fit for the purpose, which it will usually be in about twenty-four hours, remains, either to be burnished, or matted.

The proper period for this purpose can only be ascertained by experience, and varies at different seasons. The mode of distinguishing the fitness of the work to take the burnish, is to try two or three particular parts at a distance from each other; and if these take the polish well, the whole may be concluded to be in a fit state. But if the gold peel off, or be disordered by the rubbing, the work must be deemed not sufficiently dry; and if the gold bear the rubbing well, and yet receives the polish slowly, it is a proof of its being too dry, which should be prevented by watching the proper time. For the work, when too dry, both requires much more labour to burnish it, and fails at last of taking so fine a polish.

To burnish it, is to smooth and polish it with a burnisher, which is usually a dog's or wolf's tooth, or a blood-stone, an agate, or a pebble, or something else very smooth, fitted in a handle for that purpose.

To mat, is to give it a light lick in the places not burnished, with a pencil dipped in size, wherein a little vermilion sometimes has been mixed. This helps to preserve it, and prevent its flaking, when handled. Or, it is to cover the hollow parts with a colour the nearest in appearance to gold.

Some recommend for this purpose red lead, with a little vermilion ground with the white of an egg; but yellow ochre, or Dutch pink, with red lead, would better answer the end; or the *terra di Sienna*, very slightly burnt, or mixed with a little red lead, would have a much better effect, and be more durable than any other mixture so near the colour of gold in shade. Icinglass size will likewise supply the place of the whites of eggs. This operation of matting supercedes the necessity of yellowing, which is intended to give the appearance of gilding to the deeper and obscure parts of the carving where the gold cannot, nor is thought necessary to be laid on.

The last thing is to apply a vermeil, or lacquer, in all the little lines and cavities; and to stop and amend any little faults with shell-gold.

The composition here called *vermeil*, is made of gum gutta, vermilion, and a little of some ruddy brown colour, ground together with Venice varnish and oil of turpentine. Some gilders, in lieu of this, content themselves with fine lacca, or dragon's-blood, with gum-water.

Sometimes, instead of burnishing the gold, they burnish the ground or composition laid on last before it; and content themselves afterwards to wash the part over with size. This method is chiefly practised for the hands, face, and other nudities in relief; which, by this means, do not appear so very brilliant as the parts burnished; though much more so than the parts perfectly flat, or matted.

To gild a work, and yet preserve white grounds, they apply a layer of Spanish white mixed with a weak fish-glue, on all the parts of the ground whereon the yellow, or the layer next under the gold, might run.

GILDING, *Japanners*, is performed by means of gold powder, or imitations of it, cemented to the ground by a kind of gold size: for the method of preparing which, see **GOLD-SIZE**. This kind of gilding may be practised on almost any substance whatever, whether wood, metal, leather, or paper; nor is there any preparation necessary, besides making the surface on which the size is to be laid, even, and perfectly clean. Then spread the japanner's size, mixed with a due proportion of oil of turpentine and vermilion, with a brush over the work, if the whole surface is to be gilt; or draw with it, by means of a pencil, the proper figure desired, avoiding carefully any other parts; when it is almost dry, so as to be capable, by its clamminess, of receiving the gold, dip a piece of wash-leather wrapped round the finger in the gold powder, described under **SHELL-GOLD**, and rub it lightly over the sized work; or spread the powder with a soft camel's hair pencil; and with a camel's hair brush clear away the loose powder, after the gilded surface is dry. When leaf gold is used, the method of sizing must be the same as for the powders; but great care is necessary in laying them on, while the size is in a proper state of dryness.

There is a *false kind* of gilding, in which a colour of gold is given by painting and varnishes, without employing gold. Thus a very fine golden colour is given to brass and to silver, by applying on these metals a gold coloured varnish, which, being transparent, shews all the brilliancy of the metals underneath. Many ornaments of brass are varnished in this manner, which is called *gold lacquering*, to distinguish them from those that are really gilt. Silver leaves, thus varnished, are put upon leather, which is then called gilt leather; and many picture-frames have no other than this counterfeit gilding, which may be discovered by washing it with a little rectified spirit of wine; for the spirit will dissolve the varnish, and leave the silver leaf of its own whiteness. For plain picture frames, thick tin-foil may be used instead of silver; the tin leaf fixed on with glue is to be burnished, then polished with emery and a fine linen cloth, and afterwards with putty applied in the same manner; being then lacquered over with the varnish five or six times, it looks like burnished gold. (See **LACQUERING**.) Among the false gildings may also be reckoned those which are made with thin leaves of copper or brass, called Dutch leaf. In this manner are made all the kinds of what is called gilt paper. See **GILDING of Paper**.

GILDING of Books. There are various methods, with respect to the cement used, by which the edges of books or paper may be gilt. Strong gum-water or isinglass size, or glover's-size may be employed; but as the gum-water, and weaker sizes are apt to run beyond the edge, and thus cause the leaves to stick together, isinglass, melted with the addition of some common proof spirit of wine, and a sixth part of honey or sugar-candy is much to be preferred; to which must be added a third of bole armeniac well powdered.

The following composition may be used for this purpose: Take bole armeniac, and sugar-candy well powdered; mix them with the whites of eggs, beaten to an oily consistence; and the cement will be fit for use. In applying any of these cements, the paper, in quires or in books, should be well cut and polished on the edges to be gilt; and well screwed down by a press; in this state it is to be brushed over, first with a little of the cement without the sugar-candy or the bole; and when that is dry, either with the cement above given, or any other solution of gum or size with the proper proportion of the bole; after which it may be suffered to dry; and then water-polished, by rubbing it with a fine linen rag slightly moistened. It is then fit for receiving the gold, provided

it be moistened at that time; and the leaves may be then laid on, being cut according to the breadth which they are to cover, and pressed closely down by a cotton ball; and after the gilding is thoroughly dry and firm, it may be polished. See **BOOK-BINDING**, and **GILDING of Paper**.

GILDING on china-ware. The gold is very much valued on china-ware, and would be much more so, were it not that it is very liable to lose its lustre, and to rub off. The Chinese have at present a method of preventing both these accidents, in a great measure, by means of a sort of polishing, which they give it after it is laid on. They prepare for this purpose a fine piece of agate, which they polish on one surface in as perfect a manner as possible. With this they rub over the gold, as it lies on the porcelain, several times, when it first comes from the baking. This gives the gold a lustre which it would not otherwise have, and fixes it down to the ware in such a manner, that it cannot easily be got off. The principal mischief to which gold thus laid on is subject, is the tarnishing, or growing dull; this is remedied by the same sort of means. They wet the vessel, upon which they would revive the lustre of the gold, in common clean water; and while it is wet, they rub it with the same polished agate, adding a little fair water at times to keep it moist. If the gold has not been well laid on at first, this may possibly raise it or take it off in some places; but if it was originally put on with the help of this stone, as all the gold on porcelain now is, the rubbing it with it a second time never gives it any scratches, but recovers its pristine lustre and beauty. It must be observed, that the rubbing with this stone must be all done one way, both in the first laying on the gold, and in the brightening of it up afterwards. This may serve as a method for us as well as the Chinese, not only to recover the beauty of our tarnished gilt china-ware, but also to lay gold upon some of our home manufactures of this kind. *Observ. sur les Coutumes de l'Asie.* See **PORCELAIN**.

GILDING on enamel and glass, is performed by burning or annealing, *i. e.* by producing a cohesion of the gold with the glass or enamel, by the intermediation of a flux, or by producing the like effect without any. In both these methods, the gold is made to adhere to the enamel or glass, in consequence of the fusion or approach to that state, either of the flux used, or of the body of the enamel or glass itself, by which the gold is cemented to such body. The flux, when any is used, may be either simple glass of borax, or any of the preparations of fluxes powdered (see **FLUX**); and the gold is used, either in the form of leaf gold, or in that of powder made mechanically, or by precipitation. (See **GOLD powder**.) When leaf gold is employed without any flux, the enamel or glass may be moistened with a very weak solution of gum arabic, and again dried. After being thus prepared, it should be breathed upon till it becomes a little adhesive or sticky, and then laid upon a sufficient number of leaves of gold: when the gold is thus united to the enamel or glass by the cementing quality of the gum arabic, the work is ready for burning. If a flux be used, it should be finely levigated, tempered with a very weak solution of gum arabic, and very thinly spread on the part of the work to be gilded; and when the gum water is almost dry, the leaf gold should be laid on that part thus prepared for it, which is then in a state proper for burning. In the present practice, the *aurum fulminans*, or precipitation of gold by alkaline salts, is made by those who gild glass in the greatest perfection; and the volatile alkali is employed for the precipitation by the chemist, who prepares it for this purpose. But when this kind of precipitate is chosen, the use of any flux must be avoided, and a very considerable degree of

heat applied. The manner of using the precipitate powders of gold, the *aurum fulminans* excepted, as well as the leaf gold, may be varied, by adding to it or omitting any flux; but in what way soever the powder is used, it is to be tempered with the oil of spike, and worked as the enamel colours; and the quantity of flux, when any is used, may be a third of the weight of the gold. In cases where the glass is very hard, or where the opportunity of a strong heat cannot be conveniently obtained, the expedient of using a flux in the following manner may be adopted with great advantage. Grind glass of borax to a fine powder; and having tempered it with oil of spike, lay it on the glass where the gilding is to be made; then burn the glass with a degree of heat, that will cause the borax to run; and when it is cold, apply the precipitate or leaf gold, and burn it again, as in other cases. After the work is burnt, if it be intended to be burnished, a proper lustre may be given to it, by rubbing the gilded part with a dog's tooth, or with a fine agate, or iron burnishers. Handmaid to the Arts, vol. i. p. 374, &c. See *Ruby GLASS*.

Gold may be laid upon white earthen-ware or glass, by drawing your design, upon the vessel to be gilt, with japaners' gold size, moistening the size, as you find necessary, with oil of turpentine. Set the work in a clean place to dry for about an hour, and then place it so near the fire that you could but just bear the heat of it with your hand for a few seconds. Let it remain there till it feels quite tacky or clammy: then, having procured a cushion and some leaf-gold, cut it into slips of the proper size, and lay it on with a little cotton-wool. When the gold is all on, put the work into an oven to be baked for two or three hours.

Drinking glasses, with gilt edges, have been much admired in this country; the best of these are brought from Germany: those that are made in England, though equal in beauty to the foreign, being greatly inferior in the durability of the gilding. Dr Lewis made several experiments with a view of discovering this art; from which he concludes, that the gold is cemented to them by means of an intervening matter, which will adhere to glass so as not easily to be rubbed off. He tried mastich, and other resinous bodies rubbed warm on the glass, and several spirituous varnishes: but none of these were found to adhere sufficiently to the glass. He recommends to the trial of the artists in this way the harder oil varnishes: and glasses have been since prepared in England, probably on the principles which he has pointed out, with as durable gilding as those brought from Bohemia and Thuringia.

M. Zeigler, in a German translation of the "Commercium Philosophico-Technicum," describes a varnish for this purpose, with the method of using it, which appeared from his experiments to be the best. This varnish is prepared by boiling fine transparent amber, reduced to powder, in a brass vessel, to the cover of which a valve is fitted, with as much drying oil as will just cover it; and by diluting the above solution with four or five times its quantity of oil of turpentine. This varnish may be made to dry sooner, and acquires greater firmness by grinding it with a little white lead, or rather with a mixture of white lead and minium. It is to be applied very thin on the glass, and the gold leaf laid lightly on the varnished part; when the varnish is thoroughly hardened, the gold may be burnished, by laying a piece of smooth paper between the tooth or steel burnisher, and the gold. This gilding, M. Zeigler observes, is durable, and of a fine lustre. Com. Phil. Techn. p. 65, and 614.

GILDING of figures and letters on paper, and for the embellishment of manuscripts, is performed with shell-gold, tem-

pered with gum-water; or the characters may be drawn with a milky solution of gum-ammoniacum made in water, and gold-leaf applied upon them when almost dry, or if all or any part of them is become quite dry, they may be again sufficiently moistened for receiving the gold by breathing on them. Letters raised from the surface of paper or parchment, in the manner of embossed work, such as are seen on ancient manuscripts, may be formed either by friction on a proper body with a solid piece of gold, or by leaf gold. The former method is practised by tempering pulverized crystal with strong gum-water, and with this paste forming the letters; when they are dry, they are rubbed with a piece of solid gold, as in polishing, and the letters will appear as if gilt with burnished gold. The letters are formed with an embossed figure, either of the separate letters, or of whole words, cut in steel; and each letter of these stamps, when they are used, is anointed evenly with a feather dipped in oil. Then fill these concave letters with the above paste, and strike the stamps in a perpendicular direction on the paper or vellum, laid over some sheets of paper.

When the embossed letters are formed with leaf gold, the following, or a similar composition must be used. Thicken beaten whites of eggs with as much vermilion as is necessary to give them the consistence of paste; use the stamps as before; and when the letters are dry, moisten them by a small pencil with strong gum-water: and when this is almost dry, cover the letters with leaf gold, pressing it close to every part of them with cotton or soft leather; after the gilding is dry, polish it with proper burnishers. Com. Phil. Techn. p. 64 and Handmaid to the Arts, p. 450, &c.

GILDING of live-fish, as craw-fish, carps, &c. may be performed without injuring the fish, by means of a cement; which Mr. Hooke, in his posthumous papers, directs to be prepared in the following manner: Put some Burgundy pitch into a new earthen pot, and warm the vessel till it receives so much of the pitch as will stick round it; then strew some finely powdered amber over the pitch when growing cold; add a mixture of three pounds of linseed oil, and one of oil of turpentine: cover the vessel, and boil the contained ingredients over a gentle fire; grind the mixture as it is wanted, with so much pumice-stone in fine powder as will reduce it to the consistence of paint. When the fish has been wiped dry, this mixture is spread upon it, and the gold leaf laid over it, and gently pressed down; after which, the fish may be immediately put into water, and the cement will harden, and be in no danger of falling off.

GILDING on leather. See *LACQUERING*.

GILDING of metals may be done by cleaning the surface of the metal, and applying gold leaves to it, which, by means of rubbing with a polished blood-stone, and a certain degree of heat, are made to adhere perfectly well. In this manner silver leaf is fixed and burnished upon brass, in making French plate; and sometimes also gold leaf is burnished upon copper and upon iron. For this purpose, the metal, being previously polished and quite clean, is heated to about the temperature of melted lead, and covered with a double layer of gold leaf; then a blood-stone burnisher, applied gently at first, and gradually increasing the pressure, will cause the surfaces of gold and copper to touch each other in almost every point, and then adhere with a force proportioned to the completeness of the contact. The first layer being thus burnished, a second is made to adhere in the same manner, and sometimes a third, if the gilding is intended to be very solid. This method of gilding is tedious, and is subject to the almost impossibility of using a sufficient pressure without injuring the evenness of the gilded surface. In cases where these objections do not apply, there cannot be a more

effectual mode of gilding, as we perceive in the manufacture of gilt silver and copper wire. The bar, before it is committed to the wire-drawer, is plated with gold, by having several leaves of gold successively burnished down upon it, and being then subjected to the strong compression that takes place in wire-drawing, the gold and the other metal become so perfectly united, as to form, in a manner, one substance. See *GOLD Wire*.

Some metals, and particularly silver, may be gilt in the following manner: dip pieces of linen in the solution of gold by aqua regia, and then burn them to ashes; rub these ashes on the surface of the silver, well cleaned from any unctuous matter, with a wet linen rag, dipped in salt water, and the particles of gold contained in them will thus be applied to the silver, and adhere to it, without the application of heat, or intervention of any other body. Burnish the silver with a blood-stone, till it acquires the colour of gold. Most gilt ornaments on fans, snuff-boxes, and other toys of much show and little value, are nothing but silver gilt in this manner. Beckmann (*Hitt. of Inventions*, vol. i.) suggests, that this method of gilding, sometimes called dry, and sometimes cold gilding, is a German invention; and that foreigners, at least the English, were first made acquainted with it about the end of the 17th century; for Robert Southwell describes it in the *Phil. Transf.* for 1698, and says, that it was known to very few goldsmiths in Germany. See *GILDING of Metals by the fire*.

GILDING on paper, parchment, and vellum. There are various methods used for this purpose, according to the several ends which the gilding is designed to answer. But for the most part, size, properly so called, and gum-water, are used as the cements, and the powders are more generally employed than the leaf gold. See the three first articles in *GILDING*.

The gilding proper to be used with water-colours may be either with the leaf-gold or powder; the leaf-gold may be laid on the designed ground by means either of gum-water, or isinglass size; observing, that the gum-water or size be of the weaker kind, and laid sparingly on the ground, and that proper time be allowed for it to be dry; and then the gold is applied to it, as in the articles above recited; and it may be polished, if necessary, by the dog's tooth, or other kind of burnisher. In gilding larger surfaces, it will be found useful to colour the ground with the gall-stone; and when colours are to be laid on the gilding, the gall of any beast brushed over the gold will adapt it for receiving the colours. When the gold powders are used along with paintings in water-colours, they are previously formed into shell-gold. The gilding proper for the coloured paper used in binding books, and for other such purposes, is performed much in the same manner: only that the gum-water and size may be much stronger, and that they are generally conveyed to the ground by means of a wooden plate or print, or by an engraved roller, which make an impression of the intended figure or design. In this kind of gilding, the japanner's gold-size may be also commodiously employed; and this should be always used when the embossed appearance is wanted in the greatest degree; and for this purpose it should be thickened with yellow ochre, mixed with as much red-lead as the proper working of the print will admit. Instead of the genuine leaf-gold, or gold powder, the German powder, formed of the leaves called Dutch gold, is commonly used in this kind of gilding. The edges of books or paper are gilt in the manner directed under the article *Book-binding* and *GILDING of books*.

GILDING on Thread and Wire. See *GOLD-thread*, and *GOLD-wire*.

GILDING on Wood. See the three first articles in *GILDING*.

GILDING on Metals by the Fire. There are two ways of gilding by fire; viz. that with liquid gold, and that with leaf gold. For the latter, see *GILDING of Metals*, supra.

The former, technically called "water-gilding," is performed with gold amalgamated with mercury, in the proportion of about six or eight parts of mercury to one of gold.

In order to this operation, they heat some pure quicksilver in a clean crucible, and, when it is nearly boiling, put about a sixth of its weight of fine gold in thin plates heated red-hot, and stir them gently about, till the gold be found melted and incorporated into a mass with the mercury. It is then allowed to cool; and when cold, it is to be put in a piece of soft leather; and by gradual pressure, the fluid part of the amalgam, consisting almost wholly of mercury, may be forced through the pores of the leather, while the gold, combined with about twice its weight of mercury, will remain behind, forming a yellowish silvery mass, of the consistence of soft butter. This, after having been bruised in a mortar, or shaken in a strong phial with repeated portions of salt and water, till the water ceases to be fouled by it, is fit for use, and may be kept for any length of time, without injury, in a corked phial. It is of indispensable importance that the materials of this amalgam should be perfectly pure; and therefore, the mercury employed in the preparation of it should be procured from the distillation of the red precipitate (nitrous red oxyd of mercury), either alone, or mixed with a little charcoal powder.

When silver is the metal to be gilt, it is prepared for the operation by soaking it in warm dilute muriatic acid, so that the surface may be rendered perfectly clean; it is next washed in clean water, which should be two or three times changed, in order to free it from the whole of the acid; and being afterwards dried, and made moderately warm, a little gold-amalgam, also warm, is to be evenly spread upon the silver, to which it will immediately adhere. In applying the amalgam, the operator uses a little knife, or a brush made of brass wire, for the purpose; and giving the work a gentle heat before the fire, he dabs or spreads the amalgam with the brush farther and more evenly upon it.

Thus far advanced, the metal is set over the fire, upon a grate, or in a sort of cage, under which is a pan of charcoal, yielding a heat just sufficient for evaporating the mercury; by which means the mercury is raised in fumes, and leaves the gold alone adhering to the work; in proportion as the mercury, evaporating and flying off, discovers places where gold is wanting, they take care to supply them, by adding new pieces of amalgam with the knife or brush.

If a thicker gilding be required than can result from so much of the amalgam as is applied at once, the metal, after the first quantity has left its gold fixed on the surface, has more of the amalgam spread upon it. After the evaporation of the mercury from this, another quantity may be applied in the same manner. When the mercury is evaporated, so that the surface becomes uniformly of a pale yellow colour, the metal is made to undergo other operations, by which its colour and lustre are heightened. For this purpose, it is first rubbed with a scratch brush, composed of fine brass wire, till its surface is made clean and smooth, but the pale yellow colour still remains; then it is covered over with a composition called gilding wax, and again exposed to the fire till the wax be burnt off; and this application is repeated till the gold appears of a proper colour. This gilding wax is composed of bees' wax, mixed with the following substances;

viz. red ochre, verdigris, green vitriol, or alum. Thus the colour of the gilding is heightened by a perfect dissipation of some mercury remaining after the former operation. The gilt surface is then covered over with a saline composition, consisting of equal quantities of nitre, sal ammoniac, green vitriol, and verdigris, finely powdered, and mixed up into a paste with water or urine; or, this is used instead of the gilding wax. The piece of metal thus covered is heated till the mixture smokes, and quenched in water or urine. This effect seems to be produced by the acid of nitre, which is disengaged by the vitriolic acid of the alum, or other vitriolic salt, during the exposure to heat, acting upon any particles of copper which may happen to lie on the gilded surface. If the colour of the gilding be not sufficiently heightened by the first application, a succeeding one will complete the desired effect. Some artists think they give an additional lustre to their gilt work, by dipping it in a liquor prepared by boiling some yellow materials, as sulphur, orpiment, or turmeric. The only advantage of this operation is, that a part of the yellow matter remains in some of the hollows of the carved work, in which the gilding is apt to be more imperfect, and to which it gives a rich and solid appearance.

Copper, and the alloys formed by its combinations with zinc, are gilded much in the same manner as silver; but their affinity for mercury being considerably less than that of silver, it is not easy to produce a complete adhesion of the amalgam of gold to the burnished surface of these metals by the same means, and with the same evenness as in the former case. Advantage is here taken of the nitric acid for facilitating the adhesion of the copper and mercury in the following manner. The piece of copper, e. g. a button, is first cleaned by steeping it in acid and subsequent washing, and it is then burnished in a lathe, or by other means: after this, it is dipped in a neutralized solution of nitrate of mercury, and in a few seconds, on account of the strong affinity of nitric acid for copper, the mercurial salt is decomposed. The copper takes the place of the mercury, and at the same time the mercury is deposited in the metallic state, on the surface of the copper, covering it entirely, and strongly adhering to it. The gold amalgam is now applied, and the rest of the process is the same with that which has been already described. Thus a given quantity of gold may be made to cover a larger surface than in any other way of gilding on metals; five grains of gold completely gilding both the upper and under surfaces of 144 copper buttons, each of them an inch in diameter. (Phil. Mag. ix. 20.)

Iron cannot be gilt by amalgamation, unless it be previously coated with copper, by dipping it in a solution of blue vitriol, or rubbed with the vitriol itself a little moistened. Iron may also receive a golden coat from a saturated solution of gold in aqua regia, mixed with spirit of wine; because the iron, having a greater affinity for the acid, precipitates the gold from it.

In the gilding of iron, or rather steel, by means of an amalgam, peculiar difficulties occur. If recourse be had to the method of simple burnishing down, the heat requisite for this purpose will, in many cases, bring the temper of the steel too low; on such occasions the mode already described of gilding copper is sometimes practised: that is, the parts of the steel to be gilded are pencilled over with nitrate of mercury, by which they are covered with a slightly adhering coating of mercury; then the amalgam is applied, and the gilding finished in the usual way. The objections to this process are, first, that a considerable heat is required, though inferior to that requisite for burnishing down; and, secondly, that even with all possible care, the gilding is apt to be rough and to scale off. A very

considerable improvement on this method is to trace the figure of the gilding on the steel first of all with a brush charged with a strong solution of sulphated copper, in consequence of which a pretty thick plate of this metal is deposited on the steel to which it may be made to adhere with considerable firmness by means of the burnisher; thus the gilding is, in part, performed upon the copper.

A new method of gold gilding upon steel has lately been published (see Phil. Mag. xi. p. 144), possessing many advantages over the others, and capable of ultimately attaining a very high degree of perfection. This method depends upon the well-known fact, that if sulphuric ether and nitro-muriat of gold are mixed together, the ether will, by degrees, separate from the acid nearly the whole of the gold, and retain it for some time in solution in nearly a metallic state. If ether, thus charged with gold, is spread, by means of a pen or fine brush, on the surface of highly polished steel, the ether presently evaporates, leaving the gold behind in close contact with the steel, and the adhesion is considerably improved by the subsequent application of the burnisher. The dearth, and especially the rapid volatility of ether, are objections of some moment, but may be got over by using the best oil of turpentine instead of the ether, which has nearly the same efficacy in decomposing the nitro-muriat of gold, and is both cheaper, and not so very quickly evaporable.

On the subject of gilding by amalgamation, Dr. Lewis has the following remarks: "There are two principal inconveniences in this business; one, that the workmen are exposed to the fumes of the mercury, and generally, sooner or later, have their health greatly impaired by them; the other, the loss of the mercury; for though part of it is said to be detained in the cavities made in the chimnies for that purpose, yet the greatest part of it is lost. From some trials I have made, it appeared that both these inconveniences, particularly the first and most considerable one, might be in a good measure avoided, by means of a furnace of a due construction."

If the communication of a furnace with its chimney, instead of being over the fire, is made under the grate, the ash-pit door, or other apertures beneath the grate, closed, and the mouth of the furnace left open, the current of air, which otherwise would have entered beneath, enters now at the top, and passing down through the grate to the chimney, carries with it completely both the vapour of the fuel, and the fumes of such matters as are placed upon it. The back part of the furnace should be raised a little higher above the fire than the fore-part, and an iron plate laid over it, that the air may enter only at the front, where the workman stands, who will be thus effectually secured from the fumes, and from being incommoded by the heat, and at the same time have full liberty of introducing, inspecting, and removing the work.

If such a furnace is made of strong forged (not milled) iron plate, it will be sufficiently durable. The upper end of the chimney may reach above a foot and a half higher than the level of the fire; over this is to be placed a larger tube, leaving an interval of an inch, or more, all round between it and the chimney, and reaching to the height of ten or twelve feet; the higher the better. The external air, passing up between the chimney and the outer pipe, prevents the latter from being much heated, so that the mercurial fumes will condense against its sides into running quicksilver, which falling down to the bottom, is there caught in a hollow rim, formed by turning inwards a portion of the lower part, and conveyed by a pipe at one side into a proper receiver.

Another method is mentioned by authors of gilding upon metals, and also upon earthen-ware and glass; which is, to fuse gold with regulus of antimony, to pulverize this mass,

nd spread the powder upon the piece to be gilt ; afterwards to expose it to such a fire that the regulus may be evaporated while the gold remains fixed. But Dr. Lewis mentions the following inconveniencies to which this method is subject : the powder does not adhere to the piece, and cannot be equally spread ; part of the gold is dissipated along with the regulus ; glass is fusible with the heat necessary for the evaporation of regulus of antimony ; and copper is liable to be corroded by the regulus, and to have its surface rendered uneven. Lewis's Com. Phil. Techn. p. 77, &c. p. 81. 88. and 108. Macquer's Dict. Chem. Eng. edit. 1777 ; and Aikin's Dict. of Chemistry, art. GILDING.

GILDING Cushion, is formed by a few folds of flannel, or a quantity of tow or wool, secured on a piece of wood of any size from eight to fourteen inches square by a light covering of leather, and fastened tight round the edges. The surface should be perfectly flat and even, and it is usually furnished with a handle. See CUSHION.

GILDING Knife, a slip of the hollow Spanish cane, cut up

to a smooth and sharp edge, with a good penknife : this cane knife cuts the gold leaf better than one of steel, as it is apt to stick to this last. This knife may in all respects be the same as those used in painting, called " pallet knives ;" the blade of which may be four or six inches long, and somewhat more than half an inch in breadth, with a proportionable handle.

GILDING Pallet, a flat piece of wood, about three inches long, and an inch broad, covered with a piece of fine woollen cloth.

By breathing upon this pallet, to moisten the cloth a little, and then clapping it gently down upon the gold leaf, this may be raised from the cushion, and conveyed to the work to be gilded.

GILDING Tip, a tool made by fastening the long hairs of a squirrel's tail between two cards, and used for taking up the gold leaf after it is cut, and applying it to the article to be gilded.

GILDING Wax. See GILDING of Metals.

Gin

GIN, formed probably by corruption from *engine*, in *Artillery* and *Mechanics*, is a machine for raising great weights, composed of three long legs, two of which are kept at a proper distance by means of two iron or wooden bars fixed to one of the legs by means of a bolt at one end, and by the other end to the other leg with a bolt and key, so that it may be put on or off at pleasure. At three feet from the bottom is a roller moving in checks, that are fastened to these poles by two iron bands and two iron bolts. The three legs of this machine are joined together with an iron bolt, about which they move; to this bolt is fixed an iron half ring to hook on the windlass, containing two brass pulleys. When the gin stands upright, and its legs are at a proper distance, one end of the cable is fixed to the dolphins of a gun or mortar with another windlass, containing likewise two brass pulleys, and the other passes through the pulleys and round the roller, which is turned round by means of handspikes passing through the holes in the ends of the roller: while a man holds the cable tight, the gin is raised to such a height as to admit a carriage being put under it.

The gin is used in loading a timber-carriage with timber; it consists of an acute triangular frame, in the lower part of which is a roll or windlass: at the apex is a set of pulleys, and a hole to receive the top of a strong pole, which is set up opposite the triangular frame, which by this means forms a sort of tripod (or triangle, as it is commonly called among workmen) standing across a tree to be raised and loaded: the gin-rope is then reeved through a moveable block of pulleys, fastened by a chain to the tree, through

that in the top of the gin and round the roll; and then, by means of hand-spikes or levers used to the roll, the tree is drawn up to a sufficient height for the timber-carriage to be passed under it. Long trees are raised at one end first, and two of the wheels of the timber carriage are passed under them; when the other ends are raised in like manner, and the other two wheels (which are made to separate for this purpose) are passed under them, and then are joined to the other wheels by the long adjustable pole with which the carriage is furnished. See *TIMBER-Carriage*.

An erect axis or drum, turned by the force of horses coals than the horse-gins then in use, and he accordingly erected for them a water-gin, the supply for which was raised by the steam-engines employed at the pits. Since the above period, small steam-engines, called wimseys in many places, have been applied to the winding of coals, and other minerals, and have already superseded all other modes of drawing at the large collieries; these several modes of drawing or winding we shall describe particularly in the article *WINDING-Engine*.

GIN, in *Mining*, horse-gin, or coal-gin, is a machine used for drawing buckets or corves of earth or minerals up a mine-shaft or tunnel-pipe of a canal: it consists of a large vertical drum or barrel, on which a rope winds, which is conducted to pulleys over the shaft; and usually as one bucket or corve descends another ascends. See the preceding article and *Mine WINDING Engine*.

GIN-driver, is the man or boy who attends the gin-horse and turns him, when a full bucket or corve has arrived at the top of the mine-shaft.

Ginging

GINGING, in *Mining*, steining or staining, signifies the lining of a mine-shaft with stones or bricks for its support. Shallow shafts, where the measures are adapted to stand, are sunk first, and the lining of them with stone, or ginging, is begun from the bottom and carried up at once to the top : but in sinking deep shafts, after as great a depth is done at once as the nature of the measures will permit, a further depth is sunk in the bottom, beginning first within the ginging, and continuing the shaft of that diminished diameter for 12 or 18 inches, according to the soundness of the measures in that place, when it is gradually enlarged to the full size as the sinking proceeds, and sunk some yards lower, until upon reaching a bed of stone, or as great a depth as is judged safe, according to the nature of the sinking, the ginging is begun, and carried up to where the diminishing of the shafts begins ; when the same is picked out to admit the successive courses of stone or bricks, as high as is judged safe, then the removal of the remainder of the support for the first ginging

is commenced, by cutting out a piece, wide enough to admit of one or two courses of stone or bricks, being built up like a pier, which is firmly keyed or underpinned to the ginging above by means of tile-sheds or thin slate if necessary : a similar piece is then cut out and underpinned on the opposite side of the shaft, and then another between each of these, and so on, until the ginging of the lower and upper part is entirely joined all round the shafts.

The shaft is then deepened within the last ginging, and sunk, first narrow and then of its proper width, as far as is judged safe, when a new ginging is begun, and carried up, and joined to that previously finished, as above described. Solid stone-beds or permanent rocks, which are met with in sinking, are not ginged, but the shaft is sunk through such rocks, of the same diameter as the inside of the ginging, which stands upon their top and is pinned up beneath their bottoms.

Glasgow

GLASGOW, a very populous, handsome, and regularly built city, in the county of Lanark, in Scotland; situated on the north bank of the river Clyde, which is navigable for vessels of 100 tons and upwards. In ancient times, and during the prevalence of the Roman Catholic religion, Glasgow was chiefly distinguished as an archiepiscopal see, and was of course principally under the influence of the archbishop and his inferior clergy. Their power seems in those days to have been civil as well as ecclesiastical, for the charters of the most ancient corporate bodies are held by this tenure, the civil magistrates being only noticed as of subordinate rank and authority, and the freedom fines, and other emoluments are expressly appropriated to ecclesiastical purposes. The revenue of the diocese of Glasgow, if it may be estimated by the extent of lands subject to the payment of tythes, or (as they are called in Scotland) teinds, must have been very great; for those burthens extended over almost the whole of the counties of Lanark, Renfrew, Dumbarton, Ayr, Dumfries, and Galloway, comprehending the whole south-west district of Scotland, and perhaps a moiety of the most fertile land in the whole kingdom. Of this enormous revenue, since the reformation a small part, but now of great value, has been appropriated for the support of the university of Glasgow, some part for the payment of the parochial stipends, and a great part has reverted to the freeholders or their dependants, and these are constantly fluctuating as in other parts of the kingdom. The insurrections and civil wars, which devastated Scotland subsequently to the reformation, and previous to the revolution, having divested Glasgow of all that attraction which it had acquired as the archiepiscopal and occasionally as the royal residence, it appears to have been only remarkable as the occasional scene of those sanguinary and ferocious contests for which the age was conspicuous. It fell into the hands of the regent upon the defeat and flight of the unfortunate Mary Stewart at the battle of Langside, two miles south of the city. It was long afterwards battered and taken by Cromwell's army, and it

was the refuge of the defeated party, after the battle of Bothwell bridge, fought between the regent (afterwards James II.) and the Covenanters. After the revolution it seems for many years to have been a place of little importance, possessing neither a sufficient degree of wealth or refinement to render it conspicuous for elegance or luxury, nor such security or strength as to make it desirable or important as a military post. At the time of the Union with England, its whole population was estimated at only 14,000, a fact stated in the house of commons by Mr. secretary Dundas, (now lord Melville,) in one of the debates when the Irish Union was in contemplation. Subsequently to the Union, the rise of Glasgow in commercial importance, even under the successive checks of the two civil wars in 1715 and 1745, of the vastly greater commercial embarrassment, occasioned by the suspension of its colonial trade during the American contests, and all the subsequent hostilities produced by the French revolution, has been perhaps unequalled by any other place in the empire, or perhaps in the world. Its population, under the act of 1794, including its numerous suburbs, was returned at 94,000, and from the concealment which was practised from the idle fears of ignorant people, many of whom foolishly imagined that *census* to be the precursor of a military conscription, that number is supposed to be at least 30,000 short of the actual amount.

Different histories of Glasgow have been published. Of these, one published many years ago by Mr. M'Ure, one of the city clerks, was much esteemed, but is now considered as obsolete. Others have subsequently been written by Mr. Gibson about 1774, and recently by Mr. Denholm, about 1796.

The limits of this article necessarily preclude the possibility of entering much into detail, nor would it be either amusing or instructive to the general reader. We shall therefore insert what remains concerning the present state of

this great commercial and manufacturing city under the following general heads.

1. *Situation and general state of the adjacent country.*—Glasgow is situated on the north bank of the river Clyde, in N. lat. $55^{\circ} 52'$, and W. long. from the meridian of Greenwich $4^{\circ} 30'$. The extreme length from E. to W., including two suburbs, is nearly two miles, and its breadth from the cathedral or high church to the river about one mile. The lower part of the city is nearly level, and the rest is upon the southern declivity of a hill. Perhaps no city or town in Europe is, upon the whole, more regularly planned; for all the principal streets are either parallel or at right angles to each other. The chief streets are better paved than those of London, and generally wider; all the front buildings are of fine free-stone, which is found in great abundance in the immediate neighbourhood. The granite, or *ashen stone*, for paving the carriage ways, is also very plentiful close by the town. The houses are very large and lofty, being more generally upon the French plan, where every floor forms a separate lodging, accessible by a common staircase, than upon the English, where one person occupies the whole premises. The more wealthy inhabitants, however, have almost universally adopted the English taste in building. In the old part of the town it is indeed much to be regretted that there are too few public streets, so that an immense number of buildings are crowded together, many of which are accessible only by narrow passages, which are very ill calculated either for free circulation of air, admission of light, or domestic cleanliness. In the modern buildings these inconveniences are avoided, and whatever inconvenience may remain, must rather be attributed to the habits or negligence of the occupants, than to want of facilities on the part of the architects.

There are many very fine public buildings in Glasgow, the most prominent of which we shall very briefly enumerate.

Churches.—The cathedral or high church is perhaps the finest specimen in Scotland of that species of architecture, generally denominated Gothic. It was founded in the year 1123, and consecrated in the presence of king David I. in 1136. This building is more similar to that of Litchfield, than to any other of the English cathedrals, but it does not appear to have ever been completely finished, and certainly until lately little care has been used for its preservation. After the reformation it is said to have narrowly escaped destruction from the misguided zeal of the people, who confounded the building itself with the religious or superstitious ceremonies which they had exploded. It now contains two churches adapted to the Presbyterian form of worship, and the choir is used as a place of interment. The burying vaults, or cemetery, were formerly occupied as another place of worship for the barony or country parish of Glasgow; but lately a new church has been erected for this purpose at the opposite extremity of the church-yard. The great spire is very lofty, and in some degree resembles that of Salisbury. The church was dedicated to St. Mungo, or Kentigern, whose burying-place in one of the vaults is still shewn.

The remaining churches possess in general little claim to architectural encomium or description. They are six in number, viz. the college, St. Andrew's, North West, Iron, St. Enoch's, and St. George's.

St. Andrew's church is a handsome modern building, of Corinthian architecture, and is very similar in appearance to the church of St. Martin in the Fields, Westminster.

St. Enoch's and St. George's are also handsome modern buildings. Besides the established or parochial churches, there

are many dissenting chapels and meeting houses, some of which are very handsome and commodious.

Prison. This is a large and very strong building, situated in the centre of the city, adjoining to the Exchange. The lower part is occupied by the council-chambers, and rooms for the magistrates and the city clerks; the middle part of the building contains the close or lock-up rooms for those imprisoned upon criminal charges; and the two upper floors are allotted for the reception of civil debtors. The roofs are lofty, the apartments airy, and the building, upon the whole, commodious; but it is in contemplation to erect a new prison, with an enclosed space round it, where the prisoners may have the benefit of fresh air and exercise, from which they are at present precluded.

Bridewell.—This is a large building which serves as a place of confinement, or penitentiary house, for persons of depraved habits convicted of petty offences. It is very well regulated, and every means of encouragement afforded for reclaiming the prisoners from their vices, and promoting habits of industry. Many, at the period of their confinement, have thus acquired and received considerable sums, besides the expence of their subsistence, which is deducted from their earnings.

Town Hospital.—for the reception of poor persons unable to maintain themselves. The expence of this establishment is defrayed by a tax or assessment on the inhabitants, and by the proceeds of the labour of those admitted, who are supplied with work suited to their respective abilities. The inmates are aged and infirm persons and destitute children: the latter are well educated, and when arrived at a proper age, the boys are apprenticed to trades and the girls sent to service. The economy of the house is superintended weekly by gentlemen who act in rotation. The whole is very well managed.

Royal Infirmary.—a very fine modern building, from a plan of Messrs. Adams'. From 90 to 120 patients are generally under cure, but the house contains accommodation for a much larger number when required. It is supported by donations, legacies, and annual subscriptions; the funds at present amount to 10,000*l.* or 12,000*l.*, besides what has been annually expended; the annual disbursement is about 1800*l.* or 2000*l.*: the direction is vested in the lord provost, the dean of guild, convenor of the trades, professors of medicine and anatomy, president of the faculty of physicians, member for the city, and eighteen directors, ten of whom are elected by the contributors, and the others by various public bodies. The directors elected by public bodies are, one by the council, one by the merchants, one by the trades, one by the university, one by the ministers of Glasgow, and three by the faculty of physicians and surgeons. The medical assistance is afforded gratuitously.

Theatre Royal.—This superb house was erected a few years ago by voluntary subscriptions, upon transferable shares of 25*l.* each. The total cost was upwards of 15,000*l.* part of which still remains as a debt upon the property, the whole annual rent being appropriated for its gradual liquidation. The direction of the property is in sixteen directors, four of whom go out annually, in rotation, but may be re-elected. It is unquestionably the largest and most magnificent provincial theatre in Britain. The managers are merely lessees, and the lease is always given for a short period, seldom exceeding two or three years.

Concert and Assembly Rooms.—These rooms are also very splendid, and, like the theatre, were erected by voluntary subscription, upon transferable shares.

University.—The buildings of the university having been erected at various times, and in very different styles, cannot

be appreciated by any precise scale of architectural taste; but the whole has certainly an air of imposing grandeur, and is very well adapted in every respect to the purposes for which it is designed. It consists of four distinct courts, which communicate with each other, and is accessible from the high street by three gate-ways. Behind is a very large garden laid out in grass and shrubbery, with very fine walks; it is divided into three parts, of which one is appropriated as a botanical garden, another is open as a place of exercise and recreation for the students, and the third, in which the astronomical observatory is situated, is generally reserved as a place of retirement, for the professors, or of amusement for their families and friends.

The university of Glasgow was founded in the year 1450, by William Turnbull, bishop of the diocese, and then consisted of a chancellor, a dean of faculty, a principal, who was also professor of theology, and three professors of philosophy.

The professions and lectures are now as follow:

A lord chancellor; an office now honorary, and held for life.
Lord rector; also honorary—elective annually.

Dean of faculties; chosen by the professors or regents.

Principal; by the crown—present incumbent, Rev. Dr. Taylor.

Professions.

	appointed by the university.		
Divinity,	-	-	crown.
Church history,	-	-	university
Oriental languages,	-	-	do.
Natural philosophy, or physic,	-	-	do.
Mathematics,	-	-	do.
Moral philosophy, or ethics,	-	-	do.
Logic,	-	-	do.
Greek,	-	-	do.
Humanity, or Latin,	-	-	do.
Civil law,	-	-	crown.
Medicine,	-	-	do.
Anatomy and botany,	-	-	do.
Practical astronomy,	-	-	do.

Lectures.

Materia medica,	university.
Chemistry,	do.
Midwifery,	do.
Natural history,	do.
Elocution,	do.
Painting and drawing,	do.

The funds for the support of the university are in a very flourishing and prosperous state. Independently of the emoluments derived from the students, salaries and commodious houses are allotted to every professor, and these expences are defrayed from the funds at various times granted to the university: of these, the funds or tythes of the parish of Govan, form a very prominent part. The students of the five junior classes, viz. natural philosophy, moral philosophy, logic, Greek and Latin, are distinguished by wearing gowns of scarlet freeze; the students of the senior classes have no particular distinction of dress. The resident members of the university claim an exemption from all civil burthens and services, and generally from the jurisdiction of the city magistracy, but acknowledge that of the sheriff of the county, and of the supreme courts of Scotland.

The internal government of the university is vested in the principal and professors, who, in their juridical capacity, assume the title of regents. Their supreme court is a general assembly of the whole faculty, who, at a remote period, assumed the power even of capital punishment. The most

severe sentence, however, which has been passed for many years, is that of expulsion, and even this has been very rarely exercised. An inferior court is the "Jurisdictio ordinaria," consisting of at least three regents, who determine offences against the general order and peace of the university, and punish by a pecuniary fine. Each professor also possesses the power of levying small fines in his own class for negligence, contumacy, or irregularity.

The number of students in the university was estimated at 500 thirty years ago, and this number is now greatly increased. The professors and students, when assembled for the election of a rector or any other general purpose, are divided into four nations, according to the places of their respective births, viz.

Glottiani—comprehending the natives of Clydesdale, and the adjacent districts of Scotland south of the Forth.

Transforthani—the natives of Scotland, on the north of the Forth.

Rothfiani—the natives of the west highlands of Scotland and of Ireland.

Loudoniani—those of the eastern districts of Scotland, of England, America, and the colonies. The votes of these nations are decided by a majority, and the majority of nations decides the question. In cases of parity the decision is in the regents.

The university of Glasgow has recently received a most valuable acquisition, by the bequest of the museum of the late Dr. William Hunter, of London. For the reception of this valuable legacy, a very handsome building has been erected, where it is now arranged. The museum consists of a valuable collection of paintings, chiefly original; a very fine selection of anatomical preparations; a cabinet of medals, and a fine library. The medals are accounted of such value, that the trustees of the British museum are said to have offered 25,000*l.* for them, besides furnishing such duplicates as they possessed, and defraying the expence of an application to parliament for an act, so far to dissolve the testator's will. This liberal offer, however, was declined.

The public library of the university is also a collection of uncommon value. It consists of upwards of 6000 volumes, and many very rare and valuable manuscripts. In the faculty hall are some valuable paintings, particularly one of the "Martyrdom of St. Catharine."

Among the celebrated literary characters, which have belonged to this seminary, the names of Dr. Cullen, Dr. Adam Smith, and the late professor Miller, are most recently conspicuous.

There are many other public buildings in Glasgow, of which it will be necessary to confine ourselves to very brief notices.

The Trades-hall—is a fine modern building from a plan of Messrs. Adams'. It is used for the general meetings of the fourteen incorporated trades, and is also occasionally occupied for concerts, balls, and other public amusements.

Merchants' Hall—is an old building, remarkable for nothing but the spire, which is a very fine one. It is used by the body to which it belongs, in the same manner as the Trades-hall.

Public Markets.—These are very commodious, and consist of square-paved courts, surrounded by the stalls where the meat is exposed to sale. No cattle are slaughtered here, and they are kept very clean and regularly inspected.

Barracks.—These are situated in a large area walled round, and consist of three very large buildings, one of which is appropriated for officers, and two for non-commissioned officers and privates. Their complement is 1072 men, but they will lodge, on emergency, 4 or 500 more.

Town-House—a fine old building adjoining to the prison. Only one hall is retained by the body corporate. The remainder contains the Tontine hotel, which was enlarged by subscription upon lives. The coffee-room is, perhaps, the largest and finest in Europe. It is supported by annual subscription, the subscribers amounting to upwards of 1000, who pay one pound five shillings each.

Bridges.—Three of these are of stone, and a fourth was actually built in the year 1795, when the river rising rapidly, in consequence of excessive rains, it was swept away in one night when very nearly finished. The arches being very flat, and the extremities not sufficiently secured, the accident was attributed, by professional persons, to the lateral pressure. Its place has since been supplied by a very handsome wooden bridge for foot passengers. The two bridges highest upon the river are plain, but very well built and paved. The lowest, or new bridge, is very finely executed, and is esteemed one of the most complete specimens of this species of architecture in Britain.

Water-works.—The city of Glasgow, until lately, was supplied with water by pit-wells, and the water of these, although abundant in quantity, was of inferior quality both for washing and culinary purposes; as, besides other impurities, it holds in solution a considerable portion of marine acid, by which it is rendered hard and brackish. To remedy this inconvenience a public company was formed, who, at the expense of upwards of 60,000*l.*, brought water filtered from the river into every part of the city and suburbs by cast iron pipes, and from these pipes into every house, upon receiving a moderate annual payment from the proprietor or lessee. The capital necessary was raised by transferable shares of 50*l.* each. The rapidity with which those shares were bought induced others to form a separate establishment, and to raise water also from the river for the supply of the city. The first supply is drawn from the Clyde by two large steam engines, into a reservoir about two miles to the eastward of the town. From this reservoir it is filtered into another, and from thence conveyed by the pipes to a third immediately contiguous to the town. The whole lower part may be supplied from this without further forcing, but to supply the higher parts, a portion is again forced by another smaller engine to a cistern on a higher elevation, which commands every part above the former level.

The western water-work company draw their supply from the river, to cisterns situated on an eminence about one mile west of the town, where it is filtered, and conveyed by pipes, without requiring to be forced a second time. The inhabitants are left to their own free choice from which company to take their supply.

River Clyde.—The Clyde takes its rise about 60 miles to the south-east of Glasgow, in the same mountain which forms the sources of the Tweed and the Annan. Near the county town of Lanark, about 28 miles above Glasgow, it has three remarkable falls or cataracts, much visited by strangers. From Lanark to Glasgow it passes through a fine valley, richly wooded in many places, fertile and highly cultivated. From the new bridge of Glasgow, where it becomes navigable, until it terminates in St. George's, or the Irish channel, about 80 miles distant. About thirty years ago, Mr. Goldburn, an eminent engineer, was employed by the city of Glasgow to deepen the river, from the Broomilaw or harbour, to the sea-port towns of Port Glasgow and Greenock, the former situated 21, and the latter 24 miles below the city. This he effected in a very judicious, although gradual and economical manner. The beneficial effects of his plan became soon apparent, have been, every successive year, improving, and must continue

so for many years to come. He began by constructing, on either bank, projecting dykes, or jetties, into the river, at right angles, to the banks on either side, and placed at small distances from each other along the whole course of the navigation. These jetties intercept much of the earth and gravel washed down by successive floods, and thus supply the materials for ultimate contraction, without the expense of carriage. Besides this, a number of labourers are employed every summer season to drag the bottom of the river, and lodge the stuff which is withdrawn from the bottom between the projecting jetties. By the constant repetition of this simple process, a great part of the river is now contracted to less than one half of its original breadth, and has gained above four feet of additional depth. As the tonnage dues, the greater part of which is appropriated for this purpose, now exceed 6000*l.* *per annum*, these operations promise to be continued on a more extended scale than ever; and it is probable that in a few years vessels of large burthen may be brought up to the city. The largest hitherto brought up are about 130 tons, the depth of the channel being about nine feet at high water. The gentleman who now directs these improvements thinks, that in a few years this depth may be increased to 14 feet by the present plan.

It was lately proposed to improve the harbour by the construction of wet docks; but a difference of opinion having arisen respecting the controul under which these improvements were to be placed, the scheme has been suspended, but it is hoped not finally relinquished. The tonnage dues are one shilling *per* ton on merchandise, eight-pence on foreign produce, and four-pence on coals, brick, and other building materials. Manure, carried upon the river for the improvement of the adjacent country, is exempted from any tax.

The country stretching along the banks of the Clyde, for a number of miles, both above and below the city, is generally fertile, and, in most places, highly cultivated, and well enclosed. The parish of Govan, situated on the south bank of the river, is, perhaps, as highly improved as any district in Britain. Besides the natural fertility of the soil, this may be accounted for by the plentiful supply of coal, lime, and manure, which are supplied at cheap rates by water-carriage. It must also be greatly promoted by the circumstance of there being many landed proprietors, whose estates, although abundantly sufficient to maintain themselves and families in comfort and affluence under their personal superintendence, are not so large as to induce them to relinquish the profits and emoluments of cultivating their own property, which, of course, derives the united benefit of their personal skill, industry, and capital, besides that emulation which a laudable spirit of rivalry excites among them to surpass each other. The higher lands, both to the north and south, are considerably inferior, both in soil and cultivation, to those in the valley. In every direction round Glasgow, coal, lime, and iron-stone are found in great plenty, and give great advantages to the agricultural and manufacturing classes of the community.

The suburbs of Glasgow, which form the chief residences of the operative tradesmen, are the following:

Calton—a very populous village, immediately adjoining to the city on the south-east, and bordering on the *Green* of Glasgow. This village contains upwards of 20,000 inhabitants, with many manufactories, distilleries, &c. The green serves both for pasture and for the purposes of washing and bleaching. There are a commodious washing-house, and fine walks for the recreation of the inhabitants. The dues of washing and pasture form part of the city revenue. The green contains upwards of 100 acres of ground.

Bridgetown—another suburb adjoining to the former, and similar in every respect.

Gorbals—a village on the opposite bank of the Clyde, governed by a chief magistrate, appointed by the council of Glasgow, and two resident bailies.

Anderston, Brownfield, Finnieston, and Partick.—These four villages lye to the west of Glasgow, on the north bank of the Clyde; they also are residences for operative tradesmen, and contain several extensive manufactories, viz. three large cotton mills, an extensive puntfield, and porter brewery, at Anderston; a large and flourishing glass-work at Finnieston, and the very large flour-mills belonging to the incorporation of bakers at Glasgow, at Partick, where are also the ruins of an ancient castle, formerly belonging to the archbishop.

Municipal Government of Glasgow.

This, as formerly remarked, in ancient times, was almost exclusively vested in the archbishop and chapter. Since the reformation, it underwent various changes during the successive alterations of government in Scotland at large. The last arrangement made by royal and parliamentary authority, was early in the 18th century, under William and Mary. It has since been modified by the authority of the Scottish convention of royal boroughs, who exercise this power without dispute. As at present constituted, the government of the city is vested in the lord provost, three merchants, and two trades bailies, the dean of guild, or president of the merchants, the convenor, or president of the trades, the city treasurer, and master of the public works, twelve counsellors from the merchants, and eleven from the incorporated trades, in all 33 counsellors. To this body the regulation of all the public business belongs; the lord provost being president, with the casting or deciding vote in cases of parity. The courts of justice within the city are the following:

1. The circuit court of judiciary, for the cognizance of criminal actions, which is held twice a year at Glasgow, for the counties of Lanark, Renfrew, and Dumbarton, generally before two of the lords commissioners, although any one of their number is competent. This court also decides appeals in civil causes from any of the inferior courts within the district.

2. The magistrates or town court. This court is held under the authority of the magistrates, assisted by the town clerks as legal assessors. The jurisdiction of this court extends to any amount subject to an appeal to the court of session.

3. The conscience court, for the decision of petty causes under twenty shillings, where the formality of an oath is dispensed with, or any written pleading.

4. The sitting magistrate also decides daily trifling claims under five shillings. The magistrates also exercise a criminal jurisdiction in petty crimes, and punish by imprisonment, pillory, and sometimes public whipping and banishment from the city.

5. The sheriff court, for the under-ward of Lanarkshire, is also held at Glasgow, before the sheriff substitute. His jurisdiction is equal to that of the magistrates, not only within the city, but the district. The decisions of this court are subject by appeal to the sheriff depute and to the court of session.

6. The justice of peace court also decides civil causes to a limited amount, and regulates disputes between masters and servants. The appeal from this court is to the quarter sessions, and finally to the court of sessions.

7. The small debt court is held by two or more justices, for the decision of causes under 10*l*. No professional law-

yer is heard here, and the pleadings are verbal. They review their own decisions upon appeal, provided the sum decreed for be lodged with the clerk of court.

8. The commissary court is the remnant of the bishop's court. It decides for sums under 3*l*. 6*s*. 8*d*., and also in cases of defamation. Its jurisdiction extends over all the ancient bishopric.

Police Establishment.—This establishment was constituted a few years ago under the authority of a special act of parliament. The commissioners named in the act are, the lord provost and bailies, and twenty-four commissioners elected by twenty-four wards, into which number the city is divided. The qualification of a commissioner, is the occupation of a dwelling house valued at 15*l*. or upwards yearly rent; and of a voter, that of any house at 10*l*. or upwards. The business of this establishment is the lighting, cleaning, and guarding of the streets, and suppression of quarrels, riots, and other breaches of the public peace. For this purpose a master, or intendant of police officers, and watchmen are employed. A magistrate sits every morning at the police office to decide upon those who have been apprehended during the night. Where the charge is serious, he generally remits the cognizance of it to the town court, and punishes petty delinquencies by a small fine. The expence is defrayed by a tax on the valued rents of shops, warehouses, and dwelling houses, by fines levied in the course of the year by the sale of manure, from cleaning the streets, &c. The maximum of the tax is from 6*d*. to 1*s*. 3*d*. per pound of valued rent, but much less has been generally found sufficient. This institution has been always hitherto conducted with the most vigilant attention to economy, and is very popular even among those of the citizens, who strenuously opposed its original adoption.

Commerce and Manufactures.—The commercial importance of Glasgow only began to rise subsequently to the Union, and had attained no very important extent until the colonization of North America opened a wide field for the exportation of British commodities and the importation of American produce in return. Previous to the commencement of the American war in 1775, it had, however, engaged very extensively in the tobacco trade, for it appears that of 90,000 hhds. of tobacco imported into Britain in 1772, 49,000 hhds. were brought into the Clyde alone, and, in 1775, the importation was 57,143 hhds.

The operations of the war necessarily put a stop to this intercourse, to the great loss of the merchants engaged in it; many of whom have never been able to recover their debts. Upon the restoration of peace in 1783, the trade with America revived, and continued again in a flourishing state, until again recently suspended by the American non-intercourse act. In 1783, the registered vessels of the Clyde, were 386, and their tonnage 22,896, and in 1803, the number cleared outwards and inwards was as follows.

At Greenock inwards,			
Foreign trade	406 ships,	53,546 tons,	5183 men.
Coast and fishing	730 vessels,	35,532	3147
Outwards,			
Foreign trade	352 ships,	50,366 tons,	3673 men.
Coast and fishing	1016 vessels,	43,009	3326
At port Glasgow inwards,			
Foreign trade	113 ships,	18,722 tons,	1081 men.
Coast and fishing	182 vessels,	7,226	551
Outwards,			
Foreign trade	177 ships,	25,137 tons,	1692 men.
Coast and fishing	119 vessels,	7,202	424
Total	3095	238,790	17,077

From this note some idea may be formed of the extent of the trade; but many of these vessels having probably made several voyages in the course of the year, it is not to be inferred that this number of vessels actually belongs or trades to the Clyde. The articles of exportation are chiefly British manufactured goods, coals, fish, &c. and the imports European, American, and colonial produce.

The city of Glasgow had also a very considerable commercial intercourse with the eastern parts of the island, and with the northern states of Europe, until this was suspended by the events of the war. This intercourse is carried on by means of the Forth and Clyde canal, which intersects Scotland, and forms a junction between the eastern and western seas, some account of which has already been given under the article CANAL.

The manufactures of Glasgow had obtained no very great extent previous to the commencement of the American war, although they had been progressively advancing during the whole course of the eighteenth century. So far back as the reign of Charles II. indeed, some attempts had been made to introduce the manufacture of soap, refining of sugar, and some other branches, all of which proved abortive, and were discontinued. The linen manufacture was the most extensive of the various attempts made, and the most successful during the time that it lasted. It commenced about the year 1725, and continued progressively advancing until it was almost entirely superseded by the cotton towards the close of the century. The cotton manufacture, which is now unquestionably the staple trade of Glasgow, was prosecuted to very small extent until after the year 1784, but when once introduced it advanced with unprecedented rapidity. It is impossible to ascertain with any precision its actual amount either in quantity or value at any given period for want of proper data. A computation in 1791 makes the number of looms employed 15,000, and the persons who earned their subsistence by various parts of the processes of spinning, weaving, bleaching, &c. 135,000. It also estimates the total value of the goods made yearly at 1,500,000*l*. The grounds of this calculation are not stated, and little reliance can be placed on it, for the value of cotton goods has fluctuated as remarkably as the quantity has extended.

Two manufactories of earthen ware are carried on in Glasgow, but neither of them extensively. Indeed a much greater quantity of Staffordshire ware is used in the city itself than of the produce of either. Two or three rope works are also carried on, but to no great extent.

The printing of calicoes and other goods is, however, a very extensive branch of the manufacture of Glasgow and its vicinity. The most extensive of these works, are those situated upon the water of Leven, in Dumbartonshire, about 18 miles distant. The extension of the cotton trade has also greatly improved and enlarged the number of dye-works, and the manufactures of chemical preparations for the various processes of bleaching, dyeing, and printing. These works are situated in the vicinity of the city, chiefly on the banks of the river.

Of the chemical works carried on in Glasgow, some are peculiar to it.

The manufacture of Cudbear was introduced by Mr. Mackintosh so long ago as the year 1777. It is prepared from *rock-moss*, and above 2000 gallons of human urine are daily consumed in the process. The cudbear gives a dark reddish colour, and is used in the dyeing of leather, woollen stuffs, &c. The process is kept profoundly secret.

The discharging of the Turkey red dye is also peculiar to Glasgow. This process is particularly described under the article *Discharging of COLOUR*.

The manufacture of the oxy-muriate of lime, in a dry form, for the purposes of bleaching, &c. is also almost peculiar to Glasgow. Its object is to decrease the expence of bleaching by the substitution of lime for potash. This article is made to great extent by Mr. Tennent the inventor.

Iron liquor, for the use of printers, is made here by various persons, and large alum works are established in the neighbourhood. Manufactures of red and white lead are also carried on.

Miscellaneous Remarks.

It will appear that the city of Glasgow has undergone three remarkable changes. Its first state was the residence of a great archiepiscopal see, and consequently it was for many ages entirely under clerical influence and controul. Its first eminence as a commercial place arose from its favourable situation for commerce with the American and West Indian colonies, and through this traffick it made rapid advances in commercial importance during the whole course of the eighteenth century. One branch of this traffick being at least for the present suspended, it now depends chiefly on the other, and upon its manufactures for support. From the facilities of acquiring a good education, the inhabitants of Glasgow have generally added a considerable taste for literary attainment even to their commercial habits, and this style prevails, perhaps, in a degree superior to any other commercial place in Britain. The system of education is, however, rapidly adapting itself to the modern pursuits of the inhabitants, and more pains are now taken to qualify the rising generation for eminence in the counting-house than the closet. However desirable a thorough knowledge of the principles of commercial economy, and the details of business may be in a commercial community, it is still to be hoped, that all the benefits arising from intellectual attainment will not be deemed altogether nugatory, and consequently neglected. In every situation of life, they are sources of rational and innocent amusement, and, in the vicissitudes to which commercial enterprise is peculiarly exposed, may often prove of real benefit and utility to the possessor.

The city of Glasgow returns a member to the British parliament, conjunctly with the neighbouring burghs of Ruthven, Renfrew, and Dumbarton.

GLASGOW, *Port*, situated on the river Clyde, about 22 miles below the city, is a handsome small town, and was projected by the magistrates of Glasgow at the request of the merchants as a harbour for their ships and vessels. It is said that the first plan was to improve the harbour of Dumbarton for this purpose, but Dumbarton being a royal borough, the consent of its magistrates became necessary, and that when made, it was rejected by that body, who preferred the full enjoyment of their chartered privileges to the idea of sinking into the mere sea-port of Glasgow, however much their wealth, revenue, population, and general prosperity might be benefitted by such an union. If this were the case, it is one among the numberless instances where comfort and prosperity have been sacrificed to a mere empty title. The harbour of port Glasgow is good but shallow. The disadvantage of the bank, noticed in the article GREENOCK, is also much against it as a haven. At port Glasgow there is a custom-house, where the general customs of the Clyde are collected. There is here also a fine graving, or dry dock, built by the merchants of Glasgow long before that of Greenock was executed, and this circumstance alone brought many ships up to this port which now come no further than Greenock. The situation of port Glasgow is more pleasant than that of Greenock, the country more level, and better adapted for cultivation. In other respects it is certainly

els calculated for the general purposes of maritime traffick than its rival, and therefore there is little probability of its extension. Indeed the shipping belonging to Glasgow is certainly on the decrease, the foreign merchants finding it more for their advantage to freight or charter vessels for any purpose than to build or buy vessels of their own, which both consume or sink a considerable portion of their capital, and may, from the many casualties and fluctuations to which commerce in this eventful age is exposed, prove rather burthens than advantages, while the mere ship-owner, if deprived of a freight or charter-party at one port, may with greater facility seek it at another, than the person with whom freight is only a secondary and inferior consideration.

Port Glasgow is governed by magistrates, appointed by the council of Glasgow, and some resident magistrates. Its exports and imports have been already given and compared with those of Greenock under the article GLASGOW, which indeed furnishes by far the greater part of the freight to and from both ports.

There are no manufactures here of any extent, excepting those which are to be found at almost all sea-port towns, *viz.* ship building and rope spinning. Both of these are carried on to a very considerable extent. A work was erected some years ago for refining of sugar, and also a small cotton-mill, but neither have ever been prosecuted to any great extent.

A plan has been formed, and its execution is now begun, which in time may produce a great effect, both on this town and Greenock. This plan has for its object the formation of a more direct communication between Glasgow and the west sea, than the present circuitous navigation of the Clyde, by means of a navigable canal to be carried from Glasgow to Ardrossan, near Irvine, which is about thirty miles farther down the river than the present exports. This canal was projected under the sanction and patronage of the present earl of Eglintoun, (lord Ardrossan in Great Britain,) a part of whose estates lie in that neighbourhood. Its objects are two-fold. First, to facilitate the maritime intercourse of

Glasgow and Paisley with the New World, by a more direct channel and better harbour. Second, to improve the agricultural and internal state of Renfrewshire, and the northern district of Ayrshire, by affording means for the cheap conveyance of coal, lime, manure, and other heavy articles by means of the canal. Ardrossan is situated not more than thirty miles from Glasgow, by the line of the projected canal, and therefore the carriage of goods will not be more expensive or tedious than by the Clyde, for the canal being free from the constant interruptions arising from the operation of wind and tide upon the river, the time of arrival and departure may be depended upon at all seasons and in all weathers. A considerable sum has already been subscribed for the canal, and also for the harbour, and from the well-known energy and activity of his lordship's general character, there is no reason to doubt that every exertion for its speedy completion will be used.

It is natural to expect that every opposition will be given by those whose local interests will suffer by the success of this undertaking, and these comprehend many wealthy and powerful classes; but whilst some oppose, others will find it their interest to promote it, and the competition must be ultimately advantageous to the general body, however it may terminate as to those more immediately interested.

The other part of the plan is the formation of an excellent and secure harbour at Ardrossan, capable of receiving ships of large burthen, and this also is begun. The subscriptions for the two undertakings are conducted separately. The coast here is in some places reckoned dangerous during the prevalence of strong gales from the north-west, when vessels are making the land; but it is said that the bay of Lamlash, in Arran, will afford a safe and easy shelter within a few hours sail, when this may prove to be the case. The surveys, plans, and estimates for the canal and harbour of Ardrossan were made under the superintendence of Mr. Telford. It must be perfectly evident that this canal will in all events produce much benefit as it passes through the most populous and flourishing manufacturing district in Renfrewshire.

Glass

GLASS, in the general acceptation of this term among *Chemists*, denotes any substance or mixture, earthy, saline, or metallic, which is reduced by igneous fusion to the shape of a hard, brittle, uniform mass, which breaks with a conchoidal fracture, passing into splintery, and with a high degree of lustre. Most glasses of this kind are also transparent. See VITRIFICATION.

GLASS, *Vitrum*, in a more restricted sense, and as the term is commonly used in the *arts* and *manufactures*, signifies that transparent, solid, brittle, factitious substance, produced by the vitrification of siliceous earth with various salts and metallic oxyds, which is applicable to innumerable purposes of ornament and comfort, as well as of scientific investigation and research.

As to the antiquity of the term *glass*, Tacitus (Germ. c. 45.) and Pliny (l. xxxvii. c. 3.) inform us, that amber was called among the ancient Gauls or Germans by the name of *glesum* or *gleffum*; and from the similarity which glass bore to amber with respect to transparency and brightness, it acquired a name, which was, in all probability, originally the same. The word *glesum* denoted, without doubt, a shining or transparent substance, as *gleissen* expresses at present in the German language to shine; and our English word to *glissen* is derived from it, and has nearly the same signification. Ducange says that some critics were of opinion, that the word *glesum* itself implied glass rather than amber. The ancient Greeks, as it has

been observed, applied the same term (*ντλς. λςορ*) both to glass and amber. The herb with which the Britons painted their bodies had also the name of *glassum*, perhaps from the shining appearance it might give to their skins, or possibly because its ashes might be used in the making of glass. The Latins called the same plant by the name of *vitrum*, the word they used to signify glass. (Cæsar. Bell. Gall. l. v.)

We find frequent mention of this plant in ancient writers, particularly Cæsar, Vitruvius, Pliny, &c. who relate, that the ancient Britons painted or dyed their bodies with *glassum*, *guadam*, *vitrum*, &c. *i. e.* with the blue colour procured from this plant. And hence, as some have supposed, the factitious matter we are speaking of, came to be called glass, as having always somewhat of this bluishness in it.

Merret (Not. in Ant. Neri de Art. Vitrar.) gives us the following characters or properties of glass, by which it is distinguished from all other bodies, *viz.* 1. That it is an artificial concrete of salt and sand, or stones. 2. Fusible by a strong fire. 3. When fused, tenacious and coherent. 4. It does not waste or consume in the fire. 5. When melted, it cleaves to iron. 6. Ductile, when red-hot, and fashionable into any form, but not malleable; and capable of being blown into a hollowness, which no mineral is. (See DUCTILITY of *Glass*.) 7. Frangible when thin, without annealing. 8. Friable when cold. 9. Always diaphanous, whether hot or cold. 10. Flexible and elastic. 11. Dissoluble by cold and moisture. 12. Only capable of being graven, or cut with a

diamond or other hard stones, and emery. 13. Receives any colour or dye, both externally and internally. 14. Not dissolvable by aquafortis, aqua-regia, or mercury. 15. Neither acid juices, nor any other matter, extract either colour, taste, or any other quality, from it. 16. It admits of polishing. 17. Neither loses of weight nor substance, by the longest and most frequent use. 18. Gives fusion to other metals, and softens them. 19. The most pliable thing in the world, and that which best retains the fashion given it. 20. Not capable of being calcined. 21. An open glass, filled with water in the summer-time, will gather drops of water on the outside; just so far as the water on the inside reaches; and a man's breath blown upon it will manifestly moisten it. 22. Little glass balls, filled with water, mercury, and other liquor, and thrown into the fire, as also drops of green glass broken, fly asunder, with a loud noise. 23. Neither wine, beer, nor any other liquor, will make it musty, nor change its colour, nor rust it. 24. It may be cemented as stones and metals. 25. A drinking-glass, partly filled with water, and rubbed on the brim with a wet finger, yields musical notes, higher or lower, as the glass is more or less full; and this makes the liquor frisk and leap. See *ARMONICA*. For the electrical properties of glass, see *ELECTRIC*, &c.

GLASS, origin and history of. De Neri will have glass as ancient as Job; for that writer, chap. xxviii. ver. 17. speaking of wisdom, says, "gold and glass cannot equal it."

This, we are to observe, is the reading of the Septuagint, Vulgate Latin, St. Jerom, Pineda, &c. for in the English version, instead of glass, we read *crystal*; and the same is done in the Chaldee, Arias Montanus, and the king of Spain's edition. In other versions, &c. it is read *stone*; in others *beryl*: in the Italian, Spanish, French, High and Low Dutch, &c. *diamond*; in others, *carbuncle*; and in the Targum, *looking-glass*.

In effect, the original word is *zchuchith*, (זְכֻכִּית) which is derived from the root *zacac*, to purify, cleanse, shine, be white, transparent; and the same word (Exod. xxx. 34.) is applied to frankincense; and rendered in the Septuagint *pellucid*. Hence the reason of so many different renderings; for the word signifying *beautiful* and *transparent*, in the general, the translators were at liberty to apply it to whatever was valuable and transparent.

Herodotus (l. iii.) is, according to Dr. Falconer (*Manchester Memoirs*, vol. ii.), the most ancient writer (B. C. 440) who used the word *υαλο*, which is generally understood to signify glass. But he evidently does not mean artificial glass, nor crystal, but, most probably, somewhat of the talcky kind, or lapis specularis, which might readily be framed in such a manner, as to form a convenient transparent case, such as the ancient historian has described. Aristophanes (B. C. 400) seems to be the next writer who mentions glass: that poet, in his comedy called the *Clouds*, scene I. act. 2. uses the word *hyalus*, υαλῶς, which is now ordinarily rendered glass. He there introduces Strepsiades teaching Socrates a new way to pay old debts, viz. "by placing a fair transparent stone, sold by the druggists, from which the fire is struck, between the sun and the writings, and so melting away the letters thereof." This stone Socrates calls *υαλο*; which the Scholiast on Aristophanes derives from *υω*, to rain, from the likeness it bears to ice, which is rain, or water congealed; though, it must be owned, the word *υαλο* is ambiguous, and signifies *crystal* as well as *glass*; and Gorræus observes, that the ancients had a kind of yellow amber, transparent as glass, called by some *υαλο*.

Aristotle (B. C. 340) has two problems upon glass: the first, Why we see through it? The second, Why it is not malleable? If these problems be Aristotle's, which the learn-

ed doubt very much, this would properly be the earliest testimony in favour of the antiquity of glass. Theophrastus (B. C. 303) seems to have been well acquainted with glass; for he describes it as having been made of the sand of the river Belus, which was called *υαλο*, to which he adds, that the commonest kinds are made with copper. The celebrated sphere of Archimedes (B. C. 209), if it be truly described, is a remarkable instance of the perfection to which the art of making glass had been brought at that early period.

Lucian mentions large drinking glasses; and Plutarch, in his *Symposiaca*, says, that the fire of tamarisk wood is the fittest for making of glass.

Among the Latin writers, Lucretius is the first that takes notice of glass; "Nili recta foramina tranant, qualia sunt vitri;" lib. vi. v. 3. Dr. Merret, however, adds, that glass could not be unknown to the ancients, but that it must needs be as ancient as pottery itself, or the art of making bricks; for scarcely can a kiln of bricks be burnt, or a batch of pottery-ware be made, but some of the bricks and ware will be at least superficially turned to glass.

Hence, Ferrant. Imperatus, lib. xxv. cap. 7. "Glass, like the common kind, is found under ground, in places where great fires have been. Other glasses are found in round clods, like fire-stone, some brittle, others firm, &c. This fossil glass is wrought by the Americans, and used instead of iron. And no doubt but vitrifications were more common in the ancient bricks than they are in ours; as they tempered their earth two years together, and burnt them better.

Virgil (B. C. 39) compares the clearness of the water of the Eucine lake to glass. *Æneid*, v. 759. Horace (B. C. 36) is more express, and mentions glass in terms that shew its clearness and brightness to have been brought to great perfection. *Carm.* iii. *Od.* 2. *Od.* 13. In the time of Strabo, (A. D. 27) the manufacture of glass was undoubtedly well understood, and had become a considerable article. Seneca (A. D. 65) was not only well acquainted with glass as a substance, but also understood its magnifying powers when formed into a convex shape. *Quæst. Natur.* lib. iii. vi.

Pliny (A. D. 77) relates the manner of the discovery of glass. It was first made of sand, according to that author, (*Nat. Hist.* l. xxxvi. c. 66, &c.) found in the river Belus, a small river of Galilee, running from the foot of mount Carmel, out of the lake Cendevia. The part of the shore where the sand was dug did not exceed 500 paces in extent, and had been used many ages before for the same purpose. The report of its discovery was, that a merchant ship, laden with nitre, or fossil alkali, being driven upon the coast, and the crew going ashore for provisions, and dressing their victuals upon the shore, made use of some pieces of fossil alkali to support their kettles. By these means a vitrification of the sand beneath the fire was produced, which afforded a hint for the manufacture. In process of time the calc of iron, in form of the magnetical stone, came to be used along with the fossil alkali, from an idea of its not only containing iron, but glass, in a liquid form. Clear pebbles, shells, and fossil sand, were also in many places employed for the same purpose. It is said, that in India pieces of native crystal were used for that purpose; and on that account the Indian glass was preferred to any other. Pliny adds, that light and dry woods were used for the melting of glass; to which they added copper from the island of Cyprus, and the fossil alkali, especially that which is brought from the East Indies. The furnaces are kept burning without intermission, that the copper may be melted with the glass, and out of this compound are made masses of a coarse blackish colour. These lumps or masses are

again melted, and tinged of the colour required. Some of these pieces are brought to the shape required by blowing with the breath; some are ground on a lathe, and others are embossed in the same manner as silver. Sidon was formerly famous for these manufactures, as *specula* or looking-glasses were first invented there; "*siquidem etiam specula excogitaverat.*" Such is the ancient method of making glass, described by Pliny. In his time, it was made with sand found at the mouth of the river Vulturius, upon the shore, for six miles between Cumæ and the Lucrine bay. This sand was very fine, and was ground to powder with a ball or sphere and a mill. It was then mixed with three parts of the fossil alkali, either by weight or measure; and being fused, was conveyed in a liquid state into other furnaces, where it was formed into a mass, called "*ammonitrum*," (or sand combined with the fossil alkali,) which mass was melted, and became then pure glass, and a mass of white vitrified matter. The same method of making it prevailed in Spain and Gaul. Glass was likewise made to imitate the lapis Obsidianus, a substance found by a person of the name of Obsidius, in Egypt and Ethiopia. This substance was of a very black colour, yet obscurely transparent, and often placed among *specula* in the walls of rooms, to reflect the shadow of objects. It was also used for the same purpose as gems (probably for engraving upon) and even for statues. Pliny mentions, that he saw solid statues of the emperor Augustus made of this material; and the same emperor dedicated four elephants made of the same substance in the temple of Concord. It seems to have been used from great antiquity; but in the time of Pliny the artificial imitation of it by glass was used instead of the native material; and he intimates that the black colour was produced by some colouring ingredient. The Romans had likewise an opaque red kind of glass, used for plates and dishes for the table, called "*hematiton*," one of various colours, called "*myrrhinum*," a white, a clear red, a blue, and indeed most other colours. Pliny observes, that no substance was more manageable in receiving colours, or being formed into shape, than glass. The perfectly clear glass, which bore the greatest resemblance to crystal, was, however, most valued. Nero gave for two cups, with two handles to each, and of no extraordinary size, 6000 sesteria, or nearly 50,000*l.* sterling. The inferior kinds were not uncommon, as Pliny informs us, that the use of glass cups had nearly superseded those of gold and silver. We shall here add, that Pliny knew the power of a hollow glass globe, filled with water, in concentrating the rays of light, so as to produce flame in any combustible substance upon which the focus fell; and he also mentions, that some surgeons in his time made use of it as a caustic for ulcers (l. xxxvii. c. 2.). He was likewise acquainted with the comparative hardness of gems and glass, as he observes, that the lapis Obsidianus would not scratch the true gems; and he also mentions (l. xxxvii. c. 13.), the counterfeiting of the latter, in his time, as a very lucrative art, and brought to great perfection. He also says, that glass might be cut or engraven upon by means of diamonds, which art is evidenced by the antique gems so frequently found. (See GEM.) Josephus, (l. ii. c. 10.) mentions the sand of the river Belus, in Galilee, as fit for making glass.

The first time we hear of glass made among the Romans was in the reign of Tiberius, when Pliny relates that an artist had his house demolished for making glass malleable, or rather flexible; though Petronius Arbiter, and some others, assure us, that the emperor ordered the artist to be beheaded for his invention. In the time of Martial, (A.D. 84) glass was not only brought to great perfection,

and in common use for drinking vessels, but was employed (as it seems) for bottles in which wine was kept, and likewise for pots to hold flowers. (Epig. i. l. ii. 22. 40. l. iv. 86.) Galen (A.D. 143) frequently mentions glass in several parts of his works, and seems to have been well acquainted with the method of making it. Apuleius (A.D. 161) mentions the manufacture of glass cups, in his time, as highly wrought and carved in various ways, and of great value. Alexander Aphrodisiensis (A.D. 214) a Greek writer, and a commentator on Aristotle, has several remarks on glass respecting both its brittleness, especially on change of temperature, and its transparency.

The manufacturers of glass formed a company at Rome, and had a street assigned them, in the first region of the city, near the Porta Capena. A tax was laid upon them by Alexander Severus (A.D. 220) which subsisted in the time of Aurelian, and probably long after.

Mr. Nixon, in his observations on a plate of glass found at Herculaneum, which was destroyed A. D. 80, on which occasion Pliny lost his life, offers several probable conjectures as to the uses to which such plates might be applied.

Such plates, he supposes, might serve for *specula*, or looking-glasses; for Pliny, in speaking of Sidon, adds, "*siquidem etiam specula excogitaverat*;" the reflection of images from these ancient *specula* being effected by besmearing them behind, or tinging them through with some dark colour. (See MIRROR.) Another use in which they might be employed, was for adorning the walls of their apartments by way of wainscot, to which Pliny is supposed to refer by his *vitree camera* (lib. xxxvii. cap. 25. § 64.). Mr. Nixon farther conjectures, that these glass plates might be used for windows, as well as the laminae of lapis specularis and phengites, which were improvements in luxury mentioned by Seneca, and introduced in his time, Ep. xc. However, there is no positive authority relating to the usage of glass windows earlier than the close of the third century: "*Manifestius est*," says Lactantius, "*mentem esse, per oculos ea quæ sunt opposita, transpiciat, quasi per fenestras lucente vitro aut speculâri lapide obductas.*" De Opificio Dei, cap. 5. See Phil. Trans. vol. i. art. 80. p. 601. vol. lii. art. 23. p. 123.

St. Jerome (A. D. 422) speaks of windows formed of glass, melted and cast into thin plates, as being used in his time. Paulus Silentarius, a poet and historian of the 6th century (about A. D. 534), speaks of the brightness of the sun's rays, passing through the eastern windows of the church of St. Sophia, at Constantinople, which windows were covered with glass. Gregory of Tours (A. D. 571) laments the devastations frequently committed on the windows of the churches by the ravages of war. Johannes Philoponus, who lived about the year 630, or, as some say, a century earlier, not only speaks of glass, but of the panes being fastened in with plaster, much in the same way as at present.

If the opinion of Pennant, suggested under the article ANGIUM *ovum*, be well founded, we have reason to believe, that, long before the conquest of Britain by the Romans, the art of manufacturing glass into such ornaments as beads and amulets was known among the Druids; and if the art was thus applied, it is not improbable to suppose, that it was employed for more important and useful purposes, as in the manufacture of glass vessels. Nor is it likely that the Britons derived this art from the Romans, who preferred silver and gold to glass for the composition of their drinking vessels. Besides, the glass that was commonly used by the Romans was of an inferior quality, and appears from some remains of it discovered at their stations

and houses to have consisted of a thick, sometimes white, but mostly blue-green, metal.

According to venerable Bede, artificers skilled in making glass were brought over into England, in the year 674, by abbot Benedict, who were employed in glazing the church and monastery of Weremouth. According to others, they were first brought over by Wilfrid, or Wigfrid, bishop of Worcester, about the same time, or, as others think, at a later period, A.D. 726. Till this time the art of making glass, or at least of applying it to this purpose, was unknown in Britain: though glass windows did not begin to be used before the year 1180: till this period they were very scarce in private houses, and considered as a kind of luxury, and as marks of great magnificence. Italy had them first, next France, from whence they came into England.

Leo Ostiensis (A.D. 760) speaks of the windows in his time being made with glass-plates fixed in lead, and fastened together with iron. Anastasius, an historian of Rome, who was librarian to the pope, mentions, that in the pontificate of Leo III. who became pope about the year 800, painted glass in windows was in use. The statutes of the church of Traguier, in Lower Britany, about the year 1156, speak of the windows of churches and chapels being ornamented with arms and military ensigns, painted upon the glass in them. A charter of Richard II. of England, quoted by Rymer, (A.D. 1386), contains a paragraph in which is mentioned glass, together with the manufacture of it for windows.

Venice, for many years, excelled all Europe in the fineness of its glasses; and in the thirteenth century, the Venetians were the only people who had the secret of making crystal looking-glasses, and which they performed by blowing, much in the same manner as a considerable quantity of the common mirror-glass is now manufactured. The great glass-works were at Muran, or Murano, a village near the city, which furnished all Europe with the finest and largest glasses.

The glass manufacture was first begun in England in 1557: the finer sort was made in the place called Crutched Friars, in London; the fine flint glass, little inferior to that of Venice, was first made in the Savoy-house, in the Strand, London. This manufacture appears to have been much improved in 1635, when it was carried on with sea-coal or pit-coal, instead of wood, and a monopoly was granted to Sir Robert Mansell, who was allowed to import the fine Venetian flint glasses for drinking, the art of making which was not brought to perfection before the reign of William III. But the first glass plates, for looking-glasses and coach windows, were made in 1673, at Lambeth, by the encouragement of the duke of Buckingham; who, in 1670, introduced the manufacture of fine glass into England, by means of Venetian artists, with amazing success. So that within a century past, the French and English have not only come up to, but even surpassed, the Venetians, and we are now no longer supplied from abroad.

The French made a considerable improvement in the art of glass, by the invention of a method to cast very large plates, till then unknown, and scarce practised yet by any but themselves and the English. That court applied itself with a laudable industry to cultivate and improve the glass manufacture. A company of glass-men was established by letters patent; and it was provided by an arret, not only that the working in glass should not derogate any thing from nobility, but even that none but nobles should be allowed to work therein.

It was in the year 1665, under the ministry of the great Colbert, that a company for "blown-mirror-glass" was

first established near Cherbourg, in Normandy, on the plan of the Venetian manufacture; but the beautiful art of casting glass was invented in France about the year 1688, by a person of the name of Abraham Thevart; and a company was soon established for this branch of manufacture, which was first carried on at Paris, and soon after removed to St. Gobin, where it still exists in full activity, and undiminished reputation. An extensive manufactory of this kind was first established among us near Prescot in Lancashire, about the year 1773, by a respectable body of proprietors, who were incorporated by an act of parliament. They struggled for a considerable time with difficulties; but being nobly relieved and encouraged by government, they have succeeded in producing plates rivalling, if not surpassing in size, quality, or brilliancy, the most celebrated continental manufactures. This company furnishes, at Albion Place, London, plates of various dimensions, from 12 to 144 inches in length, and from 10 to 72 inches in breadth; and also convex and concave mirrors, from 12 to 36 inches in diameter.

GLASS, Ingredients of. The materials used in the composition are some saline substance and some sort of siliceous earth.

1. The first ingredient we shall specify is flint or stone. The best is that which will melt, and which is white and transparent. It is this that gives consistence and firmness to the glass. This is found principally in Italy, being a sort of stony substance called *tarso*: the next is *puocoli*, or *cuogola*, a sort of pebbles found at the bottoms of rivers, and gathered for the Venetian manufacture out of the river Po, which are said not to be inferior in whiteness to alabaster.

Indeed, nothing makes finer and clearer glass than common flint, distinguished for this use by its clear transparent, black colour; this, before it is used, must be heated red-hot, and then immediately quenched in cold water. The heat whitens it, and the water causes it to split in every direction, and facilitates the grinding of it. The charge of preparing this deters the glass-men from using it. The rounded fragments of quartz, found in the beds of rivers among mountains, are sometimes used in foreign countries, being first heated and ground to powder. Indeed, the preparation necessary for stone, in general, is to calcine, powder, and scarce it.

Ant Neri observes, that all white transparent stones, which will not burn to lime, are fit to make glass; and that all stones which will strike fire with steel, are capable of being employed in making of glass. But this latter rule, Dr. Merret observes, does not hold universally. Where proper stone cannot be had, sand is used; and it is now almost the only kind of substance employed in the British manufactures of glass. The best for this purpose is that which is white, small, and shining: examined by the microscope, it appears to be small fragments of rock crystal. For green glass, that which is of a soft texture, and more gritty; it is to be well washed, which is all the preparation it needs. Our glass-houses are furnished with white sand for their crystal glasses from Lynn in Norfolk, and Maidstone in Kent, and from the western extremity of the Isle of Wight; and with the coarser, for green glass, from Woolwich.

2. The second ingredient in the manufacture of glass is an alkali, which is either soda, or pot-ash. It is always used at first in the state of carbonate, though the carbonic acid flies off in the process. For the method of preparing each, see CARBONAT. These alkalis are used in different degrees of purity according to the required quality of the glass. The finest sort of glass requires the best pearl-ashes, purified by solution and evaporation, to dryness; but for inferior glasses coarser alkalis, such as barilla,

wood-ashes, and kelp, are employed. The ashes of fern will also yield a salt, which will make excellent glass; and, moreover, the ashes of the pods and stalks of beans, as also those of coleworts, bramble bush, millet-stalks, rushes, cyperuses, and many other plants, may be used for the like purpose, and after the same manner.

There are other fluxes used for different kinds of glass, and for various purposes. Lime, in the form of chalk, is employed in the manufacture of glass; but this must be used only in small proportions; for an excess would act powerfully on the sides of the glass-pots, in consequence of the escape of the carbonic acid from the chalk during the fusion, and, besides, it would render the glass opaque and milky in cooling, however clear it might be when hot. It is known by experience, that to 100 parts of silica and the requisite quantity of alkali, no more than about six or seven parts of quick-lime, or chalk, can be added, without affecting the clearness of the glass. Borax is another very valuable flux; but its high price restricts the use of it to the finest kinds of glass, and to those which are required to be free from specks and bubbles. A very small quantity of borax will correct any deficiency of strength in the alkali.

Of the oxyds of lead, litharge and minium are found to be of singular use in the manufacture of glass. Litharge is a powerful flux, and imparts to glass the valuable qualities of greater density and greater power of refracting the rays of light, and of bearing sudden changes from heat to cold, without being so liable to crack, and also greater tenacity when red-hot, so that it is more easily wrought. A considerable quantity of this oxyd is contained in the finer glasses; such as the London flint glass, and that which is used for the table, for lustres, for artificial gems, and for most optical purposes. Glass, however, that contains much lead, is extremely soft; and liable to be injured by hard bodies that come into contact with it; and it is also very fusible. It is also liable to be corroded by very acrid liquors. Besides, the use of lead renders it difficult to unite the silica and alkali, that a piece of glass shall be throughout of uniform density. Another ingredient occasionally used in glass is the black oxyd of manganese, called "glass-soap," from its use in clearing the glass from any accidental foulness of colour, and more especially from the green tinge, owing to the presence of iron. Scheele and Bergman in their respective "Essays," have illustrated many curious circumstances that attend the use of manganese in glasses, which are particularly detailed in Aikin's Dictionary. The manganese should be chosen of a deep colour, and free from specks, of a metalline appearance, or a lighter cast; and it requires to be well calcined in a hot furnace, and then to undergo a thorough levigation. The effect of manganese in destroying the colours of glass is accounted for by M. Montanmy, in his "Traité des Couleurs pour la Peinture en Email," in the following manner; the manganese destroys the green, olive, and blue colours of glass, by adding to them a purple tinge, and by the mixture producing a blackish brown colour; and as blackness is caused merely by an absorption of the rays of light, the blackish tinge given to the glass by the mixture of colours, prevents the reflection of so many rays, and thus renders the glass less coloured than before. But the black produced by this substance suggests an obvious reason for using it very sparingly in those compositions of glass, which are required to be very transparent.

This purple colour may be corrected by charcoal, or in the glass-house, by thrusting a billet of wood down into the melted glass, which becomes charred by the intense heat, and

causes the purple hue to vanish, with a slight effervescence of the glass, and escape of numerous small air-bubbles. On the other hand, if a small quantity of nitre is added to glass containing manganese, the purple colour is restored, or, if present, the discolouring effect of the charcoal is prevented, till the nitre becomes alkalinized by the heat, and mixes with the other ingredients of the crucible. For the explanation of these phenomena, it is observed, that the oxyd of manganese gives the purple colour only so long as it remains in its higher state of oxygenation; but when in contact with charcoal, the latter partially deoxygenates it, carbonic acid gas is formed, the cause of the bubbles observed on this occasion, and the colour is now lost. Nitre, on the other hand, is known to give out oxygen largely as soon as red-hot; and hence the manganese immediately retakes from this source the oxygen of which the charcoal had deprived it, and resumes its colouring power. The other substances which take away the colour from glass, tinged red with manganese, are all the salts with the basis of sulphuric acid, such as gypsum, sulphat of soda, &c. and also sulphur itself; likewise the oxyds of tin and iron, and of some other metals. Nevertheless these substances have this power only when in contact with charcoal. The tinging power of manganese is perfectly destroyed by the addition of arsenic in any form. Thus, a mixture of oxyd of cobalt and oxyd of manganese, in the colouring state, is of a dark purple; but on the addition of any arseniat, or of white arsenic, the manganese is made inactive, and the proper cobalt-blue alone appears. Hence we perceive the necessity, when the red colour of manganese is wanted, to avoid any thing arsenical; and nitre is also generally added to keep the manganese always at the proper state for imparting its colour. The oxyd of manganese is a very powerful flux for all earthy matters; and this, as well as lead, gives a great density to glass. The white oxyd of arsenic is another powerful and cheap flux in the making of glass; but it should be very moderately used; for it takes a longer time to mix intimately with glass, and to allow it to be perfectly clear, than any other of the additions commonly employed. For want of this the glass has a milky hue, which increases with age; and when the arsenic is in excess, the glass becomes gradually soft, and is decomposed. Besides, glass of this kind is unsafe to be used in the form of drinking vessels.

Nitre is also used, in small quantities, in the manufacture of glass, and is designed to answer particular purposes, some of which we have already specified. It not only serves to destroy the strong tinge of yellow which is found in glass, prepared with lead as a flux; but in saline glass, it is requisite, in a smaller proportion, to render it sufficiently transparent, as in the case of looking-glasses, and other kinds of plates. For an account of Mr. Dollond's excellent contrivance for destroying the colours in the object-glasses of telescopes, &c. see ABERRATION.

With regard to the several fluxes above enumerated, we may observe, in general, that the more calx of lead, or other metallic earth, enters into the composition of any glass, so much the more fusible, soft, coloured, and dense this glass is, and reciprocally.

The colours given to glass by calces of lead are shades of yellow: on the other hand, glasses that contain only saline fluxes partake of the properties of salts; they are less heavy, less dense, whiter, more brilliant, and more brittle than the former; and glasses, containing both saline and metallic fluxes, do also partake of the properties of both these substances. Glasses too saline are easily susceptible of alteration by the action of air and water; especially those in which alkalis prevail; and these are also liable to be injured

by acids. Those that contain too much borax and arsenic, though at first they appear very beautiful, quickly tarnish, and become opaque when exposed to air. By attending to these properties of different fluxes, phlogistic or saline, the artist may know how to adjust the proportions of these to sand, or powdered flints, for the various kinds of glass.

GLASS, proportion of ingredients in. Different kinds of glass require different proportions; nor have these been precisely ascertained. We shall here, and in subsequent articles, state several of the most usual and approved mixtures that have been proposed. When silica is melted with twice its weight, or more, of dry carbonated alkali, either potash or soda, the result is a very soft deliquescent vitreous mass, always more or less opaque, strongly alkaline to the taste, and which, on exposure to moist air, or more speedily in water, totally dissolves into a clear liquor, which is a solution of silica in alkali. When the same alkali is equal to the silica in weight, or does not much exceed it, the glass is now transparent, but it is still soluble in water. It is not till the alkali is diminished to about one-half of the weight of the silica, that the glass becomes perfectly hard and insoluble in any corrosive liquors, (the fluoric acid excepted,) and, in short, acquires the character of a perfect glass. This proportion, therefore, of two parts of sand to one of alkali, is usually the datum on which the doses of the alkalies actually used are regulated. Thus, if common wood ashes (of which the alkaline part is reckoned at no more than 10 per cent.) are employed, 100lbs. of these would require no more than about 20lbs. of sand. If the best Spanish barilla, containing from 45 to 50 per cent. of carbonate of soda, be used, an equal weight of sand may be added; but if purified pearl-ash be taken, it will melt down perfectly twice its own weight of sand. But glasses composed merely of pure alkali and sand, require a very strong fire for their fusion, and are hard, harsh, and difficult to break: they are therefore never used alone. As one half the weight of the sand is reckoned an abundant allowance of alkali, it follows of course that when litharge, arsenic, borax, or any other fluxes are employed, the quantity of alkali will be proportionally diminished. The following proportions are extracted from Macquer's Chemical Dictionary. - If a glass be required that is dense, fusible, and not saline, one part and a half of red lead or litharge may be mixed with one part of sand, and fused together: if equal parts of sand and of calx of lead be employed, a glass somewhat less dense and harder will be produced: if a glass be required of very little density, only saline fluxes must be employed. A glass of this kind may be composed of six parts of salt of tartar, or of potash, or of purified soda, mixed with eight parts of sand or of flints; or of four parts of any of the above-mentioned alkalies, mixed with two parts of nitre or of borax, and eight parts of vitrifiable earth. When a crystal glass is required, which shall be of an intermediate quality betwixt the metallic and saline glasses, it may be made from a mixture of one part of the above mentioned salts, one part of calx of lead, and two parts of sand or other vitrifiable earth. By varying the proportion of these ingredients, many different kinds of glasses may be produced, each of which may be good, if the quantity of each of the fluxes employed be proportionable to its vitrifying power.

GLASS, instruments for manufacturing. These are subservient to two different purposes; viz. the levigation and mixture of the ingredients, and the fusion or vitrification of them. To the former class belong horse or hand-mills, mortars and pestles, flat stones and mullers, and searces or sieves. The other sort of utensils are furnaces, with the

proper iron work, pots for containing the composition when put into the fire, and iron instruments for shifting the matter out of one into the other, in case of accidents; and for taking out small portions, in order to judge of the progress of the vitrification, and the qualities of the glass, &c. See the following articles. See also *GLASS-house*, *FURNACE*, and *GLASS-pots*.

GLASS, fusion of. When the ingredients are selected and duly proportioned, they are first calcined for a longer or shorter time, before they are put into the glass-pots. This operation is called "fritting," and is performed either in small furnaces adjoining to the proper glass-furnace, and heated by the same fuel after its chief force has been spent upon the glass-pots, or else in small furnaces or ovens constructed for this purpose. The uses of fritting are, to expel all moisture from the ingredients, by which the glass-pots would be endangered; to discharge part of the carbonic acid from the alkalies and chalk and thus to moderate the swelling in the glass-pots, and especially to cause an adhesion, or commencement of chemical union, between the alkali and silica, and metallic oxyds. This operation should be performed gradually, and carried to the point of semi-vitrification, in which the materials strongly adhere, and begin to become patty, but are still opaque and not homogeneous. This operation serves also to destroy any carbonaceous matter. When the ingredients are sufficiently fritted, they are thrown with clean iron shovels through the side-opening of the furnace into the glass-pots, the fire having been previously raised to its greatest intensity, to prevent the furnace from being chilled and to save time. The pots are charged by two or three successive portions, the preceding one being thoroughly melted down before another portion is thrown in. When filled, the side-opening is closed up with wet clay, excepting a small hole for examining the work, which closure is pulled down when the glass is well refined and about to be worked off. As soon as the frit begins to feel the action of the fire in the glass-pots, which is immediately raised to its greatest pitch, it sinks down into a soft patty state, increasing in tenacity till the fusion is complete. However, it is still opaque, from the rising of a white porous scum, known by the name of "sandiver," or "glass-gall." This substance appears to be a confused mass, consisting of all those salts contained in common alkalies, which readily melt at somewhat less than a glass-melting heat, and are either naturally soluble in a considerable degree, or have little, if any, affinity for silica, and not uniting in the composition of glass, but being lighter, rise to the top. Another heterogeneous substance, called "saudiver," is sometimes found at the bottom of the pots. This is quite different from the other, and seems to consist of a vitrified mass of arsenic and other impurities. But the scum, or proper "glass-gall," is almost entirely saline. When laded out and cooled, it turns a crumbly mass, sometimes white, at other times brown and fouled, and strongly saline, but not uniform in its composition, being sometimes merely salt, often very bitter, probably as common salt or sulphat of potash predominates. It is so volatile in a strong fire, that it is constantly dispersing from the surface of the glass in a dense vapour, which is first thick and black, afterwards whiter, and which corrodes the top of the crucible in its passage. With long continued fusion it would entirely escape in this state, if it were not skimmed off with long ladles, and sold to metal refiners as a powerful flux. Abundance of this glass-gall is attended with one of the greatest inconveniences to the maker of glass, as it requires a considerable continuance of

strong heat to dissipate the whole of it, or otherwise the glass would be full of bubbles, unsound, and having a cloudy gelatinous appearance. It is observed, that glass from potash is more likely to suffer from glass-gall than the soda-glass is, because the potash glasses are harder, and do not run so thin as the other, and the glass-gall from them does not so easily dissipate in the fire.

During this process samples for examination are drawn out of the pots with an iron rod; and the glass gradually becomes more and more flexible, dense, and less brittle, and at last the glass-gall is entirely dissipated. Whilst the heat is continued, the glass which was full of specks and bubbles is refined, and becomes beautifully clear, transparent, and colourless; and this process, which goes on from the cessation of the vapour of the glass-gall and its entire removal to the time when the glass is altogether clear and free from bubbles, is called the "refining." After this the glass is complete; but being too thin for working, it is cooled, by stopping the draught of fire round the pot which contains it, and in cooling it thickens to a fit state for being wrought. For glass that is cast into plates, less cooling is necessary, as it is required to flow very thin and hot. On an average it takes about 48 hours for the fine flint glasses, from the time when the pots are first filled till the glass is ready for working, in which state it is of a very full red colour, and possesses a singular kind of consistence and tenacity. It is just soft enough to yield with ease to any external impression, even to the force of the breath urged pretty strongly in the centre of the glowing mass, and may be bent and shaped in every possible way; and such is its tenacity, that it extends uniformly without any cracks or fissures; but when stretched out to the utmost, it forms a solid string, the diameter of which is constantly decreasing till it separates from the mass in a thin capillary thread. It stiffens as it cools, and becomes perfectly brittle and also transparent. As melted glass adheres very feebly to polished metal, it is very easily wrought with bright iron tools.

GLASS, working or blowing round.—Every kind of glass, plate-glass excepted, is formed from a hollow globe that has been produced by blowing. For this purpose the operator takes his blowing-iron, which is a hollow tube, about four or five feet long, and dipping it in the melting-pot, turns it about there till the metal adheres to the iron like some glutinous or clammy juice; he then holds it near the ground, so that the mass is extended by its own weight, and blows strongly into the tube. With his breath thus penetrating into the centre of the red-hot mass, he enlarges it into an uniform hollow globe of the requisite thickness and bulk, keeping the force of his breath upon it for a few seconds till it stiffens by cooling, and thus preventing its sinking by the compression of the denser external air. This globe, adhering by a neck to the iron rod, is formed by the dexterity of the workman, and by a variety of ingenious manœuvres into all the common utensils. As a specimen of his art, we may instance a common tumbler. The hollow globe already mentioned is taken off the iron rod by the following simple process: An assistant dips the end of a short solid iron rod into the glass-pot, and, bringing out at its extremity some of the melted glass, thrusts it immediately against the hollow of the globe at the part directly opposite to the neck, to which it firmly unites, and thus the globe is cemented by the melted glass to the second rod. The workman then wets a small piece of iron with his mouth, and lays it on the neck of the globe, which is extremely hot, and this, in a second or two, cracks it round; so that with a slight pull it comes off and detaches the hollow rod, leaving the globe open at the neck, and transferred to the second rod at the opposite

side. The open globe is again softened by holding it a few seconds over the mouth of the glass-pot, and is cut away from the open end to the form of a cup by iron shears. The operator, when employed in fashioning the globe, usually sits upon a kind of arm-chair, with its arms sloping forwards and covered with a flat smooth iron-plate; and by laying the iron rod straight before him, resting on both the arms of his seat, and twirling it backwards and forwards, the hot glass at the end is made to revolve like clay on a potter's lathe, and thus is opened, widened, or compressed at pleasure by any simple iron instrument that is pressed against it. The globular cup is thus extended easily into a cylinder, or made into the shape of a barrel, if this form be required, and is smoothed up at the edges. In order to separate it from the iron-rod, it is wetted as before at the point of attachment, and the tumbler drops off complete. This last operation leaves that burr or roughness, with sharp fragments, which is seen at the bottom of all glass-vessels, unless it be taken off by polishing. The next operation is that of cooling the vessel very gradually, called "annealing." See *Annealing of GLASS*.

GLASS, different kinds of. The manufactured glass now in use may be divided into three general kinds; white transparent glass, coloured glass, and common green or bottle-glass. Of the first kind, there is a great variety; as the flint glass, as it is called with us, and the German crystal glass, which are applied to the same uses; the glass for plates for mirrors or looking-glasses; the glass for windows and other lights; and the glass for phials and small vessels. And these again differ in the substances employed as fluxes in forming them, as well as in the coarseness or fineness of such as are used for their body. The flint and crystal, mirror, and best window glass, not only require such purity in their fluxes, as may render it practicable to free the glass perfectly from all colour: but for the same reason likewise, either the white Lynn sand, calcined flints, or white pebbles, should be used. The others do not demand the same nicety in the choice of the materials; though the second kind of window glass, and the best kind of phial, will not be so clear as they ought, if either too brown sand, or impure salts, be suffered to enter into their composition.

Of coloured glass there is a great variety of sorts, differing in their colour, or other properties, according to the occasions for which they are wanted. The differences in the latter kind depend on the accidental preparation and management of the artists by whom they are manufactured.

GLASS, Crystal. Foreigners use this term for our flint glass, and for making it they give the following directions: Take of the whitest tarso, pounded small, and searced as fine as flour, two hundred pounds; of the salt of polverine, a hundred and thirty pounds; mix them together, and put them into the furnace, called the *calcar*, first heating it. For an hour keep a moderate fire, and keep stirring the materials with a proper rake, that they may incorporate and calcine together; then increase the fire for five hours; after which take out the matter; which, being now sufficiently calcined, is called frit. From the *calcar* put the frit in a dry place, and cover it up from the dust for three or four months.

Now, to make the glass, or crystal: Take of this crystal frit, called also *bollito*; set it in pots in the furnace, adding to it a due quantity of manganese: when the two are fused, cast the fluor into fair water, to clear it of the salt, called *sandiver*; which would otherwise make the crystal obscure and cloudy. This lotion must be repeated again and again, as often as needful, till the crystal be fully purged; or, this scum may be taken off by means of proper ladles. Then set

it to boil four, five, or six days; which done, see whether it have manganese enough; and if it be yet greenish, add more manganese, at discretion, by little and little at a time, taking care not to overdose it, because the manganese inclines it to a blackish hue. Then let the metal clarify, till it becomes of a clear and shining colour; which done, it is fit to be blown, or formed into vessels at pleasure.

GLASS, Flint, as it is called in our country, is of the same general kind with that which in other places is called crystal glass. It has this name from being originally made with calcined flints, before the use of the white sand was understood; and retains the name though no flints are now used in the composition of it. This flint glass differs from the other, in having lead for its flux, and white sand for its body; whereas the flues used for the crystal glass are salts or arsenic, and the body consists of calcined flints, or white river pebbles, tarso, or such stones. This glass, on account of the quantity of litharge, which enters into its composition, is the heaviest, the most brilliant, the softest and most easy to work, and also the most expensive. It is that fine glass, of which the common and most valuable articles of white glass in domestic or ornamental use are manufactured; and besides, many optical instruments are made of this substance. To the white sand and lead a proper proportion of nitre is added, for the purposes specified in a former part of this general article, and also a small quantity of manganese, and in some works they use a proportionable quantity of arsenic to aid the fluxing ingredients. The most perfect kind of flint glass may be made by fusing with a very strong fire a hundred and twenty pounds of the white sand, fifty pounds of red lead, forty pounds of the best pearl-ashes, twenty pounds of nitre, and five ounces of manganese.

From others we have the following composition for glass of this kind, said to be of the best quality, *viz.* 120 parts of fine clear white sand, 40 of pearl-ashes well purified, 35 of litharge or minium, 13 of nitre, and a small quantity of black oxyd of manganese.

The following composition for a fine crystal glass is given by Løysel; 100 pounds of white sand, 80 to 85 of red oxyd of lead, 35 to 40 of pearl-ash, 2 to 3 of nitre, and one ounce of manganese. The specific gravity of this glass, and of the common London flint-glass, is about 3.2.

Another composition of flint glass, which is said to come nearer to the kind now made, is the following: a hundred and twenty pounds of sand, fifty-four pounds of the best pearl-ashes, thirty-six pounds of red lead, twelve pounds of nitre, and six ounces of manganese. To either of these a pound or two of arsenic may be added, to increase the flux of the composition. A cheaper composition of flint glass may be made with a hundred and twenty pounds of white sand, thirty-five pounds of the best pearl-ashes, forty pounds of red-lead, thirteen pounds of nitre, six pounds of arsenic, and four ounces of manganese; or, instead of the arsenic, may be substituted fifteen pounds of common salt; but this will be more brittle than the other. The cheapest composition for the worst kind of flint-glass, consists of a hundred and twenty pounds of white sand, thirty pounds of red-lead, twenty pounds of the best pearl-ashes, ten pounds of nitre, fifteen pounds of common salt, and six pounds of arsenic. The best German crystal glass is made of a hundred and twenty pounds of calcined flints, or white sand, seventy pounds of the best pearl-ashes, ten pounds of salt-petre, half a pound of arsenic, and five ounces of manganese. And a cheaper composition is formed of a hundred and twenty pounds of calcined flints, or white sand, forty-six pounds of pearl-ashes, seven pounds of nitre, six pounds of arsenic, and five ounces of manganese.

A glass, much harder than any prepared in the common way, may be made by means of borax in the following method: take four ounces of borax, and an ounce of fine sand; reduce both to a subtil powder, and melt them together in a large close crucible set in a wind-furnace, keeping up a strong fire for half an hour; then take out the crucible, and when cold break it, and there will be found at the bottom a pure hard glass, capable of cutting common glass like a diamond. This experiment, duly varied, may lead to several useful improvements in the arts of glass, enamels, and factitious gems, and shews an expeditious method of making glass, without any fixed alkali, which has been generally thought an essential ingredient in glass; and it is not yet known whether calcined crystal, or other substances, being added to this salt instead of sand, it might not make a glass approaching to the nature of a diamond. Shaw's Lectures, p. 426.

GLASS, Crown, is the best sort of window-glass, and differs from the flint-glass in containing no lead, nor any metallic oxyd, except manganese, and sometimes oxyd of cobalt, in minute doses, not as a flux, but for correcting the natural colour. This glass is much harder and harsher to the touch than the flint-glass; but when well made it is a very beautiful article. It is compounded of sand, alkali, either potash or soda, the vegetable ashes that contain the alkali, and generally a small portion of lime. A small dose of arsenic is often added to facilitate the fusion. Zaffre, or the oxyd of cobalt, with ground flint, is often used to correct the dingy yellow of the inferior sort of crown-glass, and by adding the blue, natural to glass coloured with this oxyd, to convert the whole into a soft light green. One ounce of zaffre is sufficient for 1000lbs. But when the sand, alkali, and lime are very fine, and no other ingredients are used, no zaffre nor corrective of bad colour is required. A very fine glass of this kind may be made by 200 parts of pretty good soda, 300 of fine sand, 33 of lime, and from 250 to 300 of the ground fragments of glass. We had formerly in London two kinds of crown glass, distinguished by the places where they were wrought; *viz.* 1. *Ratcliff crown glass*, which is the best and clearest, and was first made at the Bear-garden, on the Bank-side Southwark, but since at Ratcliff: of this there are twenty-four tables to the case, the tables being of a circular form, about three feet six inches in diameter.

2. *Lambeth crown glass*, which is of a darker colour than the former, and more inclining to green. The following composition has been recommended for the best window or crown glass, *viz.* white sand, sixty pounds; of purified pearl-ashes, thirty pounds; of salt-petre, fifteen pounds; of borax, one pound; and of arsenic, half a pound. If the glass should prove yellow, manganese must be added. A cheaper composition for window glass consists of sixty pounds of white sand, twenty-five pounds of unpurified pearl-ashes, ten pounds of common salt, five pounds of nitre, two pounds of arsenic, and one ounce and a half of manganese. The common, or green window glass, is composed of sixty pounds of white sand, thirty pounds of unpurified pearl-ashes, ten pounds of common salt, two pounds of arsenic, and two ounces of manganese. But a cheaper composition for this purpose, consists of a hundred and twenty pounds of the cheapest white sand, thirty pounds of unpurified pearl-ashes, sixty pounds of wood-ashes well burnt and sifted, twenty pounds of common salt, and five pounds of arsenic.

The manufacture of the common window glass, though made by blowing, is conducted differently from that of the flint glass articles; as it is the object to produce a large, flat, very thin plate of glass, which is afterwards cut by the

glazier's diamond into the requisite shape. Without minutely detailing the several gradations of the process, it may be here mentioned, that the workman takes a very large mass of melted glass on his hollow iron rod, and by rolling it on an iron plate and swinging it backwards and forwards, causes it to lengthen, by its own weight, into a cylinder, which is made hollow and brought to the required thinness, by blowing with a fan of breath, which persons accustomed to the business know how to command. The hollow cylinder is then opened by holding it to the fire, which, by expanding the air confined within it, (the hole of the iron rod being stopped,) bursts it at the weakest part, and when still soft, it is ripped up through its whole length by iron shears, opened out into a flat plate, and finished by annealing as usual.

The large crown glass of Messrs. Hammond and Smith is superior in quality as well as in size to that of any other manufacture. The usual diameter of the tables in other manufactures may be taken at 47 or 48 inches, with an occasional variation in a table of one or two inches: and the largest square which can be cut from these measures about 24 inches by 20, and in some circumstances one inch wider or longer. Whereas the glass of Messrs. Hammond and Smith is 60 inches in diameter, and will admit of being cut into squares of about 33 inches by 23 inches; and a little more or less. This glass is almost free from those specks, wreaths, &c. which discolour other glass, and distort the objects seen through it. It now supplies the place of German sheet glass for prints, large fashies, and exportation to those foreign markets where that glass was formerly in use.

GLASS, *French*, as also called *Normandy glass*, and formerly *Lorraine glass*, because it was made in those provinces: though it has since been made wholly in the nine glass works; five of which were in the forest of Lyons, four in the country of Eu; the last at Beaumont, near Rouen. It is of a thinner kind than our crown glass; and, when laid on a piece of white paper, appears of a dirtyish-green colour. There are but twenty-five tables of this to the case.

GLASS, *German*, is of two kinds, the *white* and the *green*: the first is of a whitish colour, but is subject to those small curved streaks, observed in our Newcastle glass, though free from the spots and blemishes thereof. The *green*, besides its colour, is liable to the same streaks as the *white*; but both of them are straighter, and less warped, than our Newcastle glass.

GLASS, *Dutch*, is not much unlike our Newcastle glass, either in colour or price. It is frequently much warped, like that, and the tables are but small.

GLASS, *Newcastle*, is that most used in England. It is of an ash-colour, and much subject to specks, streaks, and other blemishes; and, besides, is frequently warped. Leybourn says, there are forty-five tables to the case, each containing five superficial feet: some say there are but thirty-five tables, and six feet in each table.

GLASS, *Phial*, is a kind of glass betwixt the flint glass and the common bottle, or green glass. The best kind may be prepared with a hundred and twenty pounds of white sand, fifty pounds of unpurified pearl-ashes, ten pounds of common salt, five pounds of arsenic, and five ounces of manganese. The composition for green or common phial glass, consists of a hundred and twenty pounds of the cheapest white sand, eighty pounds of wood ashes, well burnt and sifted, twenty pounds of pearl-ashes, fifteen pounds of common salt, and one pound of arsenic.

GLASS, *common green bottle*, is made almost entirely of sand, lime, and sometimes clay, alkaline ashes of any kind,

as cheapness or convenience direct, and more especially of kelp in this country, of barilla, varec, and the other varieties of soda in France, and of wood ashes in many parts of Germany, and the like. To these ingredients is sometimes added the earth remaining from saline ashes, after the alkali and salts have been extracted by lixiviation, and in England flags from the iron furnaces. Bottle-glass is a very hard well-vitrified glass, which resists the corrosive action of all liquids much better than flint glass. It is used, not only for wine-bottles, but for very large retorts, subliming vessels, and other articles of the chemical apparatus; and it has for this purpose the advantage of bearing as much as a pretty full red heat without melting or sinking down into a shapeless lump, as the lead-glasses would do. The following composition is given by Loyel as a good and cheap material for bottle-glass; viz. 100 parts of common sand, 30 of varec (a kind of coarse kelp made on the western coasts of France), 160 of the lixiviated earth of ashes, 30 of fresh wood-ash, or any other kind of ash, 80 of brick-clay, and any quantity, generally about 100, of broken glass. This composition yields no glass-gall. This kind of glass is formed of sand of any kind, fluxed by the ashes of burnt wood, or of any parts of vegetables; to which may be added the scoriz or clinkers of forges. When the softest sand is used, two hundred pounds of wood-ashes will suffice for a hundred pounds of sand, which are to be ground and mixed together. The composition with the clinkers consists of a hundred and seventy pounds of wood-ashes, a hundred pounds of sand, and fifty pounds of clinkers, or scoriz, which are to be ground and mixed together. If the clinkers cannot be ground, they must be broke into small pieces, and mixed with the other matter without any grinding.

A good bottle-glass, but nearly black and opaque, has been made in France of the decomposed pulverulent basaltic earth found in the vallies of all basaltic countries. In France it abounds in the Vivarais, in Languedoc, and Auvergne. The first glass of this kind appears to have been made in 1780 by a M. Ducros at the suggestion of Chaptal, who simply melted some of this basalt without addition in a glass-pot, and formed of it two very light, black, or rather deep yellow, shining, perfect bottles. In subsequent trials by another artist, a mixture of equal parts of basalt and sand was employed, as preferable to the basalt alone; but notwithstanding a considerable demand for bottles of this material, the manufacture was abandoned for want of uniformity in the ingredients, which made them often fail. The colour of this glass was of a green-olive.

The green colour, transmitted by bottle-glass, when in its perfect state, is owing to the iron contained both in the vegetable ashes and in the sea-sand, which enter into its composition. This glass affords an instance of a semi-pellucid substance, which exhibits a blue colour by incident light, and a yellow or orange colour by that which is transmitted. See Delaval on the cause of the permanent colour of opaque bodies.

GLASS, *Plate*, is the most perfect and beautiful glass, of which all the kinds of mirrors and looking-glasses are composed. The materials of which this kind of glass is made are much the same as those of other works of glass, viz. an alkali salt, and sand.

To prepare the salt, they clean it well of all foreign matters; pound or grind it with a kind of mill, and finally sift it pretty fine.

Pearl-ashes, properly purified, will furnish the alkali salt requisite for this purpose; but it will be necessary to add borax, or common salt, in order to facilitate the fusion, and prevent the glass from stiffening in that degree of heat, in

which it is to be wrought into plates. For purifying the pearl-ashes, dissolve them in four times their weight of boiling water, in a pot of cast iron, always kept clean from rust. Let the solution be removed into a clean tub, and remain there twenty-four hours, or longer. Having decanted the clear part of the fluid from the dregs or sediment, put it again in the iron pot, and evaporate the water till the salts are left perfectly dry. Preserve them in stone jars, well secured from air and moisture.

Pearl-ashes may also be purified in the highest degree, so as to be proper for the manufacture of the most transparent glass, by pulverizing three pounds of the best pearl-ashes, with six ounces of salt-petre, in a glass or marble mortar, till they are well mixed; and then putting part of the mixture into a large crucible, and exposing it in a furnace to a strong heat. When this is red-hot, throw in the rest gradually; and when the whole is red-hot, pour it out on a moistened stone or marble, and put it into an earthen or clean iron pot, with ten pints of water; heat it over the fire till the salts be entirely melted; let it then stand to cool, and filter it through paper in a pewter cullender. When it is filtered, put the fluid again into the pot, and evaporate the salt to dryness, which will then be as white as snow; the nitre having burnt all the phlogistic matter that remained in the pearl-ashes, after their former calcination.

As to the sand, it is to be sifted and washed, till such time as the water come off very clear; and when it is well dried again, they mix it with the salt, passing the mixture through another sieve. This done, they lay them in the annealing furnace for about two hours; in which time the matter becomes very light and white: in this state they are called *frit*, or *fritta*; and are to be laid up in a dry clean place, to give them time to incorporate. They lie here for at least a year.

When they would employ this frit, they lay it for some hours in the furnace, adding to some the fragments or shards of old and ill made glasses; taking care first to calcine the shards by heating them red-hot in the furnace, and thus casting them into cold water. To the mixture must likewise be added manganese, to promote the fusion and purification.

The best composition for looking-glass plates is said to consist of sixty pounds of white sand cleansed, twenty-five pounds of purified pearl-ashes, fifteen pounds of salt-petre, and seven pounds of borax. If a yellow tinge should affect the glass, a small proportion of manganese, mixed with an equal quantity of arsenic, should be added. An ounce of the manganese may be first tried; and if this proves insufficient, the quantity should be increased.

A cheaper composition for looking-glass plate consists of sixty pounds of the white sand, twenty pounds of pearl-ashes, ten pounds of common salt, seven pounds of nitre, two pounds of arsenic, and one pound of borax.

The materials of the finest plate glass, such as that of French manufacture, are white sand, soda, and lime, to which are added manganese and zaffre, or any other oxyd of cobalt for particular colouring purposes. The sand is of the finest and whitest kind, which should be previously passed through a wire sieve, moderately close, into water, in which it should be well stirred about and washed. The sharpest grained sand is preferred, and it is found that grains of moderate size melt with the alkali sooner, than the very fine dust or the larger fragments. The alkali is always soda, which is preferable to potash, as glasses made with soda are found to be softer and to flow thinner when hot, and yet to be equally durable when cold. Besides, the

neutral salts with the basis of soda which constitute the glass-gall in this instance, such as the muriat and sulphat of soda, appear to be dissipated more readily by the fire than the corresponding salts of potash. The soda that is used is considerably pure, or such as is separated from the rough ashes of barilla, and other soda plants by lixiviation. Lime adds to the fusibility of the other materials, supplying the use of litharge in the flint-glass; but excess of it would impair the colour and solidity of the glass. About 1-15th of the whole is as much as can properly be used; but some reduce the quantity to 1-24th. The decolouring substances are azure, or cobalt blue, and manganese. Besides these, there is always a great quantity of the fragments of glass, collected from the waste of the manufacture, which are made friable by quenching in water when hot, and used in this state together with the fresh materials. As to the quantities and proportions of the ingredients, much latitude is allowed. The following are said to produce a very fine glass; viz. 300lbs. of sand; 200lbs. of soda; 30lbs. of lime; 32 ounces of manganese; three ounces of azure; and 300lbs. of fragments of glass. In the manufactory at St. Gobin secrecy is observed with regard to the materials; but it is affirmed, and with much probability, that borax is used in small quantity.

Of the materials now enumerated the sand, soda, lime, and manganese are first mixed together with more care than for ordinary glass, and they are fritted in small furnaces built for this purpose, the heat being gradually raised to a full red-white, and then kept with frequent stirring till the materials undergo no farther change, nor yield any kind of vapour. The azure and glass fragments being already in a state of perfect vitrification are not added till just at the end of the process, which lasts about six hours. When the materials are thus prepared, they are fit for plate-glass, to be formed either by blowing or casting. The largest glasses at St. Gobin are run; the middle-sized and small ones are blown.

Blowing looking-glass plates. The work-houses, furnaces, &c. used in the making of this kind of plate-glass, are the same, except that they are smaller, and that the carquoisses are disposed in a large covered gallery, over-against the furnace, as those in the following article, to which the reader is referred.

After the materials are vitrified by the heat of the fire, and the glass is sufficiently refined, the workman dips in his blowing iron, six feet long, and two inches in diameter, sharpened at the end, which is put in the mouth, and widened at the other, that the matter may adhere to it. By this means he takes up a small ball of matter, which sticks to the end of the tube by constantly turning it. He then blows into the tube, that the air may swell the annexed ball: and carrying it over a bucket of water, which is placed on a support at the height of about four feet, he sprinkles the end of the tube to which the matter adheres, with water, still turning it, that by this cooling, the matter may coalesce with the tube, and be fit for sustaining a greater weight. He dips the tube again into the same pot, and proceeds as before; and, dipping it in the pot a third time, he takes it out, loaded with matter, in the shape of a pear, about ten inches in diameter, and a foot long, and cools it at the bucket; at the same time blowing into the tube, and, with the assistance of a labourer, giving it a balancing motion, he causes the matter to lengthen; which, by repeating this operation several times, assumes the form of a cylinder, terminating like a ball at the bottom, and in a point at the top. The assistant is then placed on a stool three feet and a half high; and on this stool there are two

upright pieces of timber, with a cross beam of the same, for supporting the glass and tube, which are kept in an oblique position by the assistant, that the master workman may with a puncheon set in a wooden handle, and with a mallet make a hole in the mass: this hole is drilled at the centre of the ball that terminates the cylinder, and is about an inch in diameter. When the glass is pierced, the defects of it are perceived; if it is tolerably perfect, the workman lays the tube horizontally on a little iron tressel, placed on the support of the aperture of the furnace. Having exposed it to the heat for about half a quarter of an hour, he takes it away, and with a pair of long and broad shears, extremely sharp at the end, widens the glass, by insinuating the shears into the hole made with the puncheon, whilst the assistant, mounted on the stool, turns it round, till, at last, the opening is so large as to make a perfect cylinder at bottom. When this is done, the workman lays his glass upon the tressel, at the mouth of the furnace, to heat it: he then gives it to his assistant on the stool, and with large shears cuts the mass of matter up to half its height. There is at the mouth of the furnace an iron tool, called *pontil*, which is now heating, that it may unite and coalesce with the glass just cut, and perform the office which the tube did before it was separated from the glass. This *pontil* is a piece of iron, six feet long, and in the form of a cane or tube, having at the end of it a small iron bar, a foot long, laid equally upon the long one, and making with it a T. This little bar is full of the matter of the glass, about four inches thick. This red-hot *pontil* is presented to the diameter of the glass, which coalesces immediately with the matter round the *pontil*, so as to support the glass for the following operation. When this is done, they separate the tube from the glass, by striking a few blows with a chisel upon the end of the tube, which has been cooled; so that the glass breaks directly, and makes this separation, the tube being discharged of the glass now adhering to the *pontil*. They next present to the furnace the *pontil* of the glass, laying it on the tressel to heat, and reddening the end of that glass, that the workman may open it with his shears, as he has already opened one end of it, to complete the cylinder; the assistant holding it on his stool as before. For the last time, they put the *pontil* on the tressel, that the glass may become red-hot, and the workman cuts it quite open with his shears, right over-against the fore-mentioned cut; this he does as before, taking care that both cuts are in the same line. In the mean time, the man who looks after the carquaisse, comes to receive the glass upon an iron shovel, two feet and a half long without the handle, and two feet wide, with a small border of an inch and a half to the right and left, and towards the handle of the shovel. Upon this the glass is laid, flattening it a little with a small stick a foot and a half long, so that the cut of the glass is turned upwards. They separate the glass from the *pontil*, by striking a few gentle blows between the two with a chisel. The glass is then removed to the mouth of the hot carquaisse, where it becomes red-hot gradually; the workman, with an iron tool, six feet long, and widened at the end in form of a club at cards, four inches long, and two inches wide on each side, very flat, and not half an inch thick, gradually lifts up the cut part of the glass, to unfold it out of its form of a flattened cylinder, and render it smooth, by turning it down upon the hearth of the carquaisse. The tool, already described, being insinuated within the cylinder, performs this operation, by being pushed hard against all the parts of the glass. When the glass is thus made quite smooth, it is pushed to the bottom of the carquaisse, or annealing furnace, with a small iron raker, and ranged there with a little iron hook. When

the carquaisse is full, it is stopped and cemented as in the case of run glasses, and the glass remains there for a fortnight to be annealed; after which time, they are taken out to be polished. A workman can make but one glass in an hour, and he works and rests for six hours alternately.

It may be observed, that looking-glasses, thus blown, should never be above forty-five, or at most fifty inches long, and of a breadth proportionable. Those exceeding these dimensions, as we frequently find among the Venice glasses, cannot have the thickness sufficient to bear the grinding; and, besides, are subject to warp, which prevents them from regularly reflecting objects. Whereas plates as large as nine feet in length and proportionally wide, have been manufactured by casting.

Casting or running large Looking-glass plates. This art, as we have observed in the *History of Glass*, is of French invention. It is owing to the *Sieur Abraham Thevart*, who first proposed it to the court of France, in 1688.

It is performed much like the casting of sheet-lead among the plumbers; and by means hereof we are not only enabled to make glasses of more than double the dimensions of any made by the Venetian way of blowing; but also to cast all kinds of borders, mouldings, &c.

The furnaces for melting the materials of this manufacture are of large size, being about 18 feet long and 15 wide; and those for annealing the glasses, when formed, are much more so. Round a melting-furnace, there are at least twenty-four annealing furnaces or ovens; each from twenty to twenty-five feet long; they are called carquaisse: each carquaisse has two tiffarts, or apertures, to put in wood, and two chimnies. Add, that beside the annealing furnaces, &c. there are others for making of frit, and calcining old pieces of glass.

All these furnaces are covered over with a large shed; under which are likewise forges, and work-houses for smiths, carpenters, &c. continually employed in repairing and keeping up the machines, furnaces, &c. as also lodges, and apartments for these, and the other workmen, employed about the glass, and keeping up a perpetual fire in the great furnace; so that the glass-house, as that in the castle of St. Gobin, in the forest of Fere, in the *Seissonois*, appears more like a little city, than a manufactory.

The inside of furnaces is formed of a sort of baked earth, or refractory clay, proper to sustain the action of fire; and the same earth serves also for melting-pots, cisterns, &c. The furnaces seldom last above three years; after which they are to be rebuilt, from bottom to top; and to keep them good, even for that time, the inside must be refitted every six months, at which time the fire is extinguished. The melting-pots are as big as wine hogheads, about three feet in height, and in diameter; and contain above two thousand weight of metal. They are in the form of an inverted and truncated cone. The cisterns, or pans, called "*cuvettes*," are much smaller, being about thirty-six inches long, eighteen inches wide, and as many deep; and serve for the conveyance of liquid glass, which is drawn out of the pots to the casting tables. They do not contain much more than a sixth, or when large plates are cast, a third of the pots.

When the furnace is in condition to receive the pots and cisterns, they heat it red-hot, which requires fifty cords, or a hundred cart-loads of wood. That kind of wood which emits the largest and brightest flame, without much resinous smoke, is preferred. This done, they fill the pots with the materials, or soda and sand, which is done at several times, to facilitate the fusion. When the matter is sufficiently vitrified, refined, and settled, which usually happens in

thirty-six hours, they fill the cisterns, which are in the same furnace, and which are left there about six hours longer, till such time as they appear all white through the excessive heat.

To get the cisterns with the metal out of the furnace, they make use of a large iron chain which opens and shuts with hooks and eyes. From the middle of this, on each side, arise two massive iron pins, by which, with the assistance of pulleys, the cisterns are raised upon a kind of carriage of a proper height; and thus conducted to the table where the glass is to be run. The cistern is then raised above the tables with an engine, in form of a crane, by means of two iron bars, so contrived as to throw the cistern into an inclined position, which discharges a torrent of matter, all on fire, with which the table prepared for this purpose is presently covered.

The table on which the glass is to be run, is of smooth thick copper-plate, about ten feet long, and six feet broad. It is supported on a wooden frame, with truckles, for the convenience of removing from one carquaille, or annealing furnace, to another, in proportion as they are filled.

Or, when each pot has a casting table, it is strongly supported by masonry, and contiguous to each table on the same level are the annealing ovens, upon which, being flat, the glass, when cast and sufficiently cooled, may be slid from off the copper-table without much difficulty. The tops of the flat ovens and the tables are on a level with the corresponding opening of the furnace, whence the cuvettes or cisterns are withdrawn. When the glass is melted and fined in the manner already stated under the article *Flint Glass*, the cuvette or cistern, previously made hot in the furnace, is filled out of the pot with a copper ladle, about ten inches in diameter, fixed to an iron handle seven feet long, properly supported on an iron stay by two workmen; and after remaining in the furnace for some hours, till the samples taken out for trial appear to be quite clear and limpid, the door of the furnace is opened, and the cuvette is pulled out and removed to the side of the copper table. It is then skimmed with an instrument consisting of a copper blade set in iron, and hoisted for the discharge of its contents on the table, in the manner already mentioned.

To form the thickness of a glass, and to make the surface smooth and even, there are two iron rulers or rims, placed round the edge of the table; and on these rest the two extremes of a kind of roller, or hollow heavy cylinder of copper, turned after being cast, and about 500 pounds in weight, which serves to drive the liquid matter before it to the end of the table, or mould. The iron rulers being moveable, and capable of being set closer, or farther apart, at pleasure, determine the width of the glasses, and retain the matter, that it does not run off at the edges. The waste glass, if any, falls into a vessel of water, and is reserved for the next melting.

As soon as the matter is arrived at the end of the table, and the glass is come to a consistence, examined by the directors of the manufacture, and approved, they shove it off into the annealing furnace, with an iron raker, as wide as the table, that has a handle two fathoms long; being assisted by workmen on the other side of the carquaille, who, with iron hooks, pull the glass to them, and range it in the carquaille, which holds six large glasses.

What is most surprising throughout the whole of this operation, is the quickness and address wherewith such massy cisterns, filled with a flaming matter, are taken out of the furnace, conveyed to the table, and poured on it, the glass spread, &c. The whole is inconceivable to such as

have not been eye-witnesses of that surprising manufacture.

As fast as the cisterns are emptied, they carry them back to the furnace and take fresh ones, which they empty as before. This they continue to do, so long as there are any full cisterns; laying as many plates in each carquaille as it will hold, and stopping them up with doors of baked earth, or clay, and every chink with cement, as soon as they are full, to let them anneal, and cool again, which requires about fourteen days.

The first running being dispatched, they prepare another, by filling the cisterns anew, from the matter in the pots; and after the second, a third, and even a fourth time, till the melting-pots are quite empty.

The cisterns at each running should remain at least six hours in the furnace to whiten; and when the first annealing furnace is full, the casting table is to be carried to another. It need not here be observed, that the carquailles, or annealing furnaces, must first have been heated to the degree proper for them. It may be observed, that the oven full, or the quantity of matter commonly prepared, supplies the running of eighteen glasses, which is performed in eighteen hours, being an hour for each glass. The workmen work six hours, and are then relieved by others.

When the pots are emptied, they take them out, as well as the cisterns, to scrape off what glass remains, which otherwise would grow green by continuance of fire, and spoil the glasses. They are not filled again in less than thirty-six hours, so that they put the matter into the furnace, and begin to run it every fifty-four hours.

The manner of heating the large furnaces is singular enough; the two tisors, or persons employed for that purpose, in their shirts, run round the furnace without making the least stop, with a speed scarce inferior to that of the lightest courier: as they go along, they take two billets, or pieces of wood, which are cut for the purpose; these they throw into the first tiffart; and continuing their course do the same for the second. This they hold without interruption for six hours successively; after which they are relieved by others, &c. It is surprising that two such small pieces of wood, and which are consumed in an instant, should keep the furnace to the proper degree of heat; which is such, that a large bar of iron, laid at one of the mouths of the furnace, becomes red-hot in less than half a minute.

It is computed, that a furnace, before it be fit to run glass, costs above three thousand five hundred pounds; that at least six months are required for the building it anew, and three months for the refitting it; and that when a pot of matter bursts in the furnace, the loss of matter and time amounts to above two hundred and fifty pounds.

The glass, when taken out of the melting-furnace, needs nothing farther but to be ground, polished, and foliated. But before these operations are performed, they cut and square the edges of the plates; which is performed with a rough diamond, passed along the surface of the glass, upon a square ruler, like that of the glaziers, and made to cut into the substance of the glass to a certain depth. This cut is then opened by gently knocking with a small hammer on the under side of the glass, just under it; by which means the piece comes off, and the roughnesses of the edges are removed by pincers. The plates are then laid by for grinding,

polishing, and silvering; which see respectively. See also LOOKING-GLASS.

GLASS, Annealing or Nealing of. The operation of annealing of glass is performed in a peculiar furnace called the *leer*, which consists of two parts, the *tower* and *leer*. The vessels, as soon as made, are placed by the workmen on the floor of the former to anneal: which done, they are drawn slowly in a sort of pan, called *fraches*, by an operator called the *farole-man*, all along the latter, the space of five or six yards, to give them time to cool gradually; so that when they reach the mouth of it, they are found quite cold. Merret, Not. to Neri, p. 243, seq.

This annealing is generally performed in a hot chamber, built for the purpose, at the top of the glass-house, above the crucibles, and a little below the chimney. Without this precaution, the glass would be liable to fly and break, by the least change of heat and cold, by the smallest scratch, and sometimes without any apparent external cause. The hard glasses, and those especially that are made with alkali and earths, require much more annealing than the softer and more fusible glasses, containing in their composition much litharge.

The particles of glass by annealing are supposed to lose part of their springiness, and their brittleness at the same time. A gradual heating or cooling of glass, according to Dr. Hook, anneals or reduces its parts to a texture more loose, and easy to be broke; but withal more flexible than before. And hence in some measure the phenomena of glass-drops.

Some of the phenomena depending on the fragility of unannealed glass deserve the attention of the curious. Those of the lachrymæ, or glass-drops, were among the first taken notice of; and it has also been observed, that hollow bells made of unannealed glass, with a small hole in them, will fly to pieces by the heat of the hand only, if the hole by which the internal and external air communicate be stopped with a finger. Phil. Trans. N° 477. § 3. See RUPERT'S Drops.

But lately some vessels made of such unannealed glass have been discovered, which have the remarkable property of resisting very hard strokes given from without, though they shiver to pieces by the shocks received from the fall of very light and minute bodies dropped into their cavities. Of this kind is the "Bologna phial." These glasses may be made of any shape; all that needs be observed in making them, is to take care that their bottoms may be thicker than their sides. The thicker the bottom is, the easier do the glasses break. One whose bottom is three fingers breadth in thickness, flies with as much ease at least as the thinnest glass. Some of these vessels have been tried with strokes of a mallet sufficient to drive a nail into wood tolerably hard, and have resisted fracture. They also resist the shock of several heavy bodies let fall into their cavities, from the height of two or three feet. For instance, musket-balls, pieces of iron, or other metal; pyrites, jasper, wood, bone, &c. but this is not surprising, as other glasses of the same size do the same. But the wonder is, that taking a shiver of flint of the size of a small pea, and letting it fall into the glass only from the height of three inches, in about two seconds the glass flies, and sometimes in the very moment of the shock; nay, a bit of flint, no larger than a grain, dropt into several glasses successively, though it did not immediately break them, yet they all flew, being set by, in less than three quarters of an hour. Phil. Trans. ibid. p. 509.

Some other bodies produce a like effect with flint: for instance, sapphire, porcelain, diamonds, hard tempered steel,

as also marbles, such as boys play with; to which add pearls from the animal kingdom.

The experiment succeeded also when the glasses were held in the hand, rested on a pillow, put in water, or filled with water. It is also remarkable, that the glasses broke upon their bottoms being slightly rubbed with the finger, though some of them did not fly till half an hour after the rubbing.

If the glasses be every where extremely thin, they do not break in these circumstances.

Some have pretended to account for these phenomena, by saying, that the bodies dropped into these vessels cause a concussion, that is stronger than the cohesion of the parts of the glass, and that consequently a rupture of the same must ensue. But why does not a ball of gold, silver, iron, copper, or several other bodies, even a thousand times heavier than a shiver of flint, equally cause this concussion, and break the glasses?

Mr. Euler has endeavoured to account for these appearances from his Principles of Percussion. He thinks this experiment entirely overthrows the opinion of those who measure the force of percussion by the *vis viva*; and he thinks the principles he has established give a clear solution of this phenomenon. According to these principles, the extreme hardness of the flint, and also its angular figure, which makes the space of contact with the glass vessel extremely small, ought to cause an impression on the glass vastly greater than lead or any other metal; and this may account for the flint's breaking the vessel, though the bullet, even falling from a considerable height, does no damage. Mem. Acad. Berlin, 1745, p. 47.

Hollow cups, made of the green bottle-glass, some of them three inches thick at bottom, were instantly broken, by a shiver of flint weighing about two grains, though they had resisted the shock of a musket ball from the height of three feet. Phil. Trans. ibid. p. 515.

"The precise mechanical cause of this disposition to crack in unannealed glass, is very difficult to explain," says Aikin (Dict.), "but generally speaking, it is supposed to be the forcible contraction of the outer part by sudden cooling, whilst the inner portion is still soft and half-fluid, so that the whole fixes with a permanent strain or inequality of pressure of one part upon the other; and as glass is extremely elastic, though brittle, any force which tears asunder a portion, however small, of the tense part, communicates a strong and sudden impulse over the whole mass." "This most singular phenomenon," (of the Rupert's drop) says the same ingenious chemist, in consequence of his own experiments, "is obviously owing to some permanent and very strong inequality of pressure, for when they are heated so red, as to be soft and merely let to cool of themselves, this property of bursting is entirely lost, and, at the same time, the specific gravity of the drop is increased. The peculiar brittleness of the Bologna phial is also removed by again heating and cooling slowly." The common window-glass, when badly annealed, is cut by the diamond with difficulty, and the cut often flies in a direction different from what was intended, or the glass entirely breaks.

Among other more common defects of glass, we may mention its liability to be acted upon by corrosive liquors, as is the case when too much saline flux has been used. As impenetrable as glass is to the common menstrua, we find it eaten by the air in length of time, when exposed in old windows; but the effects of its being kept in a subterraneous place are much more strange. Corrichius tells us, that at

the time when he was at Rome, there was dug up a whole house from under the kitchen garden of a citizen. The house had been buried there ten ages, and there were found in it several glass urns, or lacrymatories. The glass of these had no holes made in it, as our old glass in chamber-windows has, but still retained its smooth surface and transparency; but it was split into a vast number of thin laminæ, which were as pellucid and fine as Muscovy glass; and in some places were tinged with all the beautiful colours that art could have given. We are not acquainted perfectly with the ancient way of working their glass; but it is not probable there could be any thing particular in the formation of the vessel, to determine it to split thus into flakes; but that glass of the same kind, in any form, would have done the same. *Borrich de Ortu Chemiæ.*

There are other visible imperfections in glass, materially injuring its soundness and beauty, and enumerated by Aikin (*Dict. art. Glass*) under the denominations of *striae*, *threads*, *tears*, and *knots*. The former are undulating waves in the glass, arising from the imperfect mixture of the materials, and their different specific gravities. Accordingly, we may observe, that the most transparent glass is subject to bubbles and veins, the methods of preventing which are yet little known; and this is an inconvenience by which Mr. Dollond's excellent discovery is affected; for the flint-glass which he uses is peculiarly subject to small veins, that disturb the rays in their passage, and render the vision confused. This effect is owing to the density of these veins being greater than that of the rest of the glass, as appears from their image received on white paper, when the glass is held between the paper and a candle, or other luminous object: for this image of a

thus received, is a line brighter than the rest of the image of the glass, and this bright line is defined by a dark edge on each side. But the bright line evidently shews a convergency of rays, which can only be effected by the veins being denser than the medium in which they are placed. The reason why flint glass is more subject to veins than other glass is, says the translator of Macquer's Chemical Dictionary, because it is composed of materials of more different densities.

Mr. Macquer, with a view of improving the manufacture of this glass, proposes to facilitate the union of the calx of lead and sand, of which it is composed, by depriving the calx of lead, as much as possible, of its phlogiston, which may be done by combining the vitriolic acid with minium, or red-lead, and exposing this composition to the operation of fire, to disengage it from the acid; and also by giving these two substances the greatest possible degrees of fluidity and mobility, which may be done by mixing with the composition of them a considerable quantity of solvents. *Hist. Acad. Scienc. for 1773.*

Threads in glass, are those streaky filaments which arise from the vitrification of the clay; being generally green, and rendering the glass more liable to crack at these parts. But one of the worst defects (says Aikin, *ubi supra*), is "*tears*, or drops of vitrified clay falling down from the furnace into the pots, and entangled with the glass. Articles made of glass with this defect, are always very brittle, and generally break of themselves by slight changes of heat and cold." Small bubbles appear in glass not sufficiently refined by a continuance of the melting heat; and these may be owing to a deficiency of flux, so that the glass is less fusible, and the bubbles cannot easily be disengaged. "Hence," says the author now cited, "the soft fusible glasses with much lead are much less liable to this fault than the hard, green bottle-glass, which is made only of alkali

and earth." The *knots* in glass "arise either from a portion of sand that has escaped vitrification, and remains entangled in the glass, or from a remaining quantity of glass-gall; or from bits of the crucible which may be accidentally knocked off by the iron instruments used in the working."

GLASS of Antimony. See *Oxyds of ANTIMONY* and *VITRUM Antimonii ceratum*.

GLASS, Axungia of. See *AXUNGIA*, *SANDIVER*, and *GLASS, supra*.

GLASS of Bora. See *BORAX*.

GLASS, Colouring of, to imitate gems. See *GEMS*.

GLASS, Gold-coloured This kind of glass may be made by taking ten pounds of either of the compositions for hard glass, omitting the salt-petre; and for every pound adding an ounce of calcined borax; or, if this quantity doth not render the glass sufficiently fusible, two ounces; ten ounces of red tartar, of the deepest colour, two ounces of manganese, and two drams of charcoal of fallow, or any other soft kind. Precipitate of silver baked on glass will stain it yellow, and likewise give a yellow colour on being mixed with and melted with forty or fifty times their weight of vitreous compositions; the precipitate from aqua-fortis by fixed alkali seems to answer best. Yellow glasses may also be obtained with certain preparations of iron, particularly with Prussian blue. But Dr Lewis observes, that the colour does not constantly succeed, nor approach to the high yellow of gold, with silver or with iron. The nearest imitations of gold which he has been able to produce, have been effected with antimony and lead. Equal parts of the glass of antimony, of flint calcined and powdered, and of minium, formed a glass of a high yellow; and with two parts of glass of antimony, two of minium, and three of powdered flint, the colour approached still more to that of gold. The last composition exhibited a multitude of small sparkles interspersed through its whole substance, which gave it a beautiful appearance in the mass, but were really imperfections, owing to air-bubbles.

Neri directs, for a gold-yellow colour, one part of red tartar, and the same quantity of manganese, to be mixed with a hundred parts of frit. But Kunkel observes, that these portions are faulty; that one part, or one and a quarter of manganese, is sufficient for a hundred of frit; but that six parts of tartar are hardly enough, unless the tartar is of a dark red colour, almost blackish; and that he found it expedient to add to the tartar about a fourth of its weight of powdered charcoal. He adds, that the glass swells up very much in melting, and that it must be left unstirred and worked as it stands in fusion. Mr. Samuel More, in repeating and varying this process, in order to render the colour more perfect, found that the manganese is entirely essential to the gold colour, and that the tartar is no otherwise of use, than in virtue of the coaly matter, to which it is in part reduced by the fire; the phlogiston or inflammable part of the coal appearing in several experiments to be the direct tinging substance. Mr. Pott also, in his *Neue Wichtige Physikalisch-Chymische Materien*, &c. printed in 1762, observes, that common coals give a yellow colour to glass; that different coaly matters differ in their tinging power; that caput mortuum of foot and lamp-black answer better than common charcoal; and that the sparkling coal which remains in the retort after the rectification of the thick empyreumatic animal oils, is one of the most active of these preparations. This preparation, he says, powdered, and then burnt again a little in a close vessel, is excellent for tinging glass, and gives yellow, brown, reddish, or blackish colour, according to its quantity: but the frit must not be very

hard of fusion; for, in this case, the strong fire will destroy the colouring substance before the glass melts, and he has found the following compositions to be nearly the best; *viz.* sand two parts, alkali three parts; or sand two, alkali three, calcined borax one; or sand two, alkali two, calcined borax one: and though salt-petre is hardly used at all, or very sparingly, for yellow glasses, as it too much volatilizes the colouring substance; yet here for the most part a certain proportion of it, easily determined by trial, is very necessary; for without it, the concentrated colouring matter is apt to make the glass too dark, and even of an opaque pitchy blackness. It does not certainly appear that there is any material diversity in the effects of different coals; the difference being probably owing to the different quantities of the inflammable matter which they contain; so that a little more shall be required of one kind than of another, for producing the same degree of colour in the glass. Nor does the softness or fusibility of the frit appear to be in any respect necessary.

Gold-coloured spangles may be diffused through the substance of glass, by mixing the yellow talcs with powdered glass, and bringing the mixture into fusion. See Lewis's *Com. Phil. Techn.* p. 223. 626, &c.

GLASS for counterfeiting lapis lazuli. See *Lapis LAZULI*.

GLASS resembling opal. See *OPAL* and *GEMS*.

GLASS, *Ruby*. The way to give the true fine red of the ruby, with a fair transparency, to glass, is as follows. Calcine in earthen vessels gold dissolved in aqua regia, the menstruum being evaporated by distillation, more aqua regia added, and the abstraction repeated five or six times, till it becomes a red powder. This operation will require many days in a hot furnace; when the powder is of a proper colour, take it out; and when it is to be used, melt the finest crystal glass, and purify it, by often casting it into water; and then add, by small quantities, enough of this red powder to give it the true colour of a ruby, with an elegant and perfect transparency. Neri. See *GEMS*.

The process of tinging glass and enamel by preparations of gold, were first attempted about the beginning of the 17th century. Libavius, in one of his tracts, entitled *Alchymia*, printed in 1606, conjectures that the colour of the ruby proceeds from gold, and that gold dissolved, and brought to redness, might be made to communicate a like colour to factitious gems and glass. On this principal Neri, in his "*Art of Glass*," dated 1611, gives the process above recited. Glauber, in 1648, published a method of producing a red colour by gold, in a matter which is of the vitreous kind, though not perfect glass. For this purpose he ground powdered flint or sand with four times its weight of fixed alkaline salt; this mixture melts in a moderately strong fire, and when cold looks like glass, but exposed to the air runs into a liquid state. On adding this liquor to solution of gold in aqua regia, the gold and flint precipitate together in form of a yellow powder, which by calcination becomes purple; by mixing this powder with three or four times its weight of the alkaline solution of flint, drying the mixture, and melting it in a strong fire for an hour, a mass is obtained, of a transparent ruby colour, and of a vitreous appearance, which nevertheless is soluble in water, or by the moisture of the air, on account of the redundancy of the salt. The honourable Mr. Boyle, in a work published in 1680, mentions an experiment, in which a like colour was introduced into glass without fusion; for, having kept a mixture of gold and mercury in digestion for some months, the fire was at last immoderately increased, so that the glass burst with a violent explosion; and the lower part of the glass was found tinged throughout

of a transparent red colour, hardly to be equalled by that of rubies. See Porosity of Bodies, in Shaw's Abridgment of Boyle's Works, vol. i. p. 459; and Appendix to the Sceptical Chemist.

About the same time Cassius is said to have discovered the precipitation of gold by tin, and that glass might be tinged of a ruby colour by melting it with this precipitate: though he does not appear, says Dr. Lewis, from his treatise *De Auro*, to have been the discoverer of either. He describes the preparation of the precipitate and its use, but gives no account of the manner of employing it; only that he says, one dram of gold, duly prepared, will tinge ten pounds of glass. See *GOLD precipitate with tin*.

This process was soon after brought to perfection by Kunckel; who says, that one part of the precipitate is sufficient to give a ruby colour to 1280 parts of glass, and a sensible redness to upwards of 1000 parts; but that the success is by no means constant. Kunckel also mentions a purple-gold powder, resembling that of Neri, which he obtained by inspissating solution of gold to dryness, abstracting from it fresh aqua regia three or four times, till the matter appears like oil; then precipitating with strong alkaline ley, and washing the precipitate with water. By dissolving this powder in spirit of salt, and precipitating it again, it becomes, he says, extremely fair; and in this state he directs it to be mixed with a due proportion of Venice glass.

Orfchal in his treatise entitled *Sol sine Velle*, gives the following process for producing a very fine ruby. He directs the purple precipitate, made by tin, to be ground with six times its quantity of Venice glass into a very fine powder, and this compound to be very carefully mingled with the frit or vitreous composition to be tinged. His frit consists of equal parts of borax, nitre, and fixed alkaline salt, and four times as much calcined flint as of each of the salts; but he gives no directions as to the proportion of the gold precipitate, or mode of fusion. Hellot describes a preparation, which mixed with Venice glass, was found to give a beautiful purple enamel. This preparation consists of equal parts of solution of gold, and of solution of zinc in aqua regia, mixed together with the addition of a volatile salt prepared from sal ammoniac, in quicklime, in sufficient quantity to precipitate the two metals. The precipitate is then gradually heated, till it acquires a violet colour. However, though a purple or red colour, approaching to that of ruby, may, by the methods above recited, be baked on glass or enamels, and introduced into the mass by fusion, the way of equally diffusing such a colour through a quantity of fluid glass is still, says Dr. Lewis, a secret. The following process for making the ruby glass was communicated to Dr. Lewis by an artist, who ascribed it to Kunckel. The gold is directed to be dissolved in a mixture of one part of spirit of salt, and three of aqua-fortis, and the tin in a mixture of one part of the former of these acids with two of the latter. The solution of gold being properly diluted with water (see *GOLD precipitate*, &c.) the solution of tin is added, and the mixture left to stand till the purple matter has settled to the bottom. The colourless liquor is then poured off, and the purple sediment, while moist and not very thick, is thoroughly mixed with powdered flint or sand. This mixture is well ground with powdered nitre, tartar, borax, and arsenic, and the compound melted with a fire of 1100°.

See *GLASS* & *Com. Phil. Techn.* p. 171. 621, &c.

GLASS, *white-opaque*, and *semi-transparent*, may be made of ten pounds of either of the compositions for hard glass, and

one pound of well calcined horn, ivory, or bone; or an opaque whiteness may be given to glass, by adding one pound of very white arsenic to ten pounds of flint glass. Let them be well powdered and mixed, by grinding them together; and then fused with a moderate heat, till they are thoroughly incorporated. A glass of this kind is made in large quantities at a manufacture near London, and used not only for different kinds of vessels, but as a white ground for enamel in dial-plates and snuff-boxes, which do not require finishing with much fire, because it becomes very white and fusible with a moderate heat.

GLASS, Yellow. See *Golden-coloured GLASS*.

GLASS-balls, which are circular or otherwise shaped hollow vessels of glass, may be coloured within, so as to imitate the semi-pellucid gems. The method of doing it is this: make a strong solution of ichthyocolla, or isinglass, in common water, by boiling; pour a quantity of this while warm into the hollow of a white glass vessel; shake it thoroughly about, that all the sides may be wetted, and then pour off the rest of the moisture. Immediately after this, throw in red lead, shake it and turn it about, throw it into many places with a tube, and the moisture will make it stick and run in waves and pretty figures. Then throw in some of the painter's blue smalt, and make it run in waves in the ball as the red-lead; then do the same with verdigris, next with orpiment, then with red lake, all well ground; always casting in the colours in different places, and turning the glass, that the moisture within may run them into the waves. Then take fine plaster of Paris, and put a quantity of it into the ball; shake it also nimbly about; this will every where stick firmly to the glass, and give it a strong inner coat, keeping all the colours on very fairly and strongly.

These are set on frames of carved wood, and much esteemed as ornaments in many places. Neri.

GLASS-drops. See *RUPERT'S drops*.

GLASS, Foliating of. See *FOLIATING* and *LOOKING-GLASS*.

GLASS-gall, or *sandiver*, is the scum of the glass pots, which arises during the vitrification of the frit. See *GLASS*, *supra*.

GLASS, gilding of. See *GILDING of enamel and glass*.

GLASS, grinding of. See *GRINDING*.

GLASS-house Furnace, is the place in which the ingredients or materials of glass are fused and vitrified. There are three kinds of furnaces used in the glass-works. The *first*, called the "calcar," serves for preparing or calcining the frit. It is made like an oven, 10 feet long, eleven broad, and two deep. The fuel, which is sea-coal, is put in a trench, on one side of the furnace; and the flame reverberates from the roof back upon the frit. The coals burn in an iron grate, and the ashes fall thence into holes underneath.

The *second* is the "working furnace," in which the ingredients are melted, and the glass is made. Its figure is round, resembling a dome; three yards in diameter, and two high, supported on arches, beneath which is a large space for a brick and copious draught of cold air from without: round the inside there are arranged eight or more pots, and on these piling-pots, every where closed except at one side opening, which communicates with a small recess formed by the alternate projections of the masonry and flues of the oven or kiln, in which recess the workmen stand. The furnace has two partitions; the lower, separating the pots from the fire-place, has a circular hole in the centre covered with a grate, through which the flame passes from the fire-place into the furnace, being afterwards reverberated from the arched sides and roof to the melting-pots, and passing out with the smoke through the top of the dome, which is lengthened into a chimney for

the space of a few feet. The *second* partition divides this from the leer or annealing furnace; through the boccas, or working holes, when there are more than one, the metal is taken out of the pots, and the pots put into the furnace: these boccas are stopped with moveable covers, made of lute and brick to screen the eyes of the workmen from the fire; and sometimes on each side of the bocca is a boccarella, out of which coloured glass, or finer metal is taken from the piling-pot. To the furnace likewise occasionally belong ovens, or holes near the leer, for the calcining of tartar, iron, &c.

The leer, which serves to anneal and cool the vessels, and which Agricola makes a particular furnace, consists of a tower, besides the leer; the tower lies directly over the melting furnace, with a partition betwixt them about a foot thick, having an aperture called *occhio*, or *lumella*, through which the flame or heat ascends out of the furnace into the tower: on the floor or bottom of this tower, the vessels, fashioned by the artist, are set to be annealed; and as the flame has here a less degree of intensity than that which is sustained by the pots, the vessels, after they have been formed, cool slowly and gradually. This has usually two boccas, or mouths, by which the glasses are put in with a fork, and placed on the floor. The leer is an avenue, five or six yards long, continued to the tower; through this the glasses, when annealed, are drawn in iron pans, called *fraches*, by which they come to cool by degrees, being quite cold by the time they reach the mouth of the leer, which enters the "farusel," or room where the glasses are to be set.

The *third* is the "green-glass furnace," which is a kind of compound of all the former. It is made square, (the two former being circular,) having an arch at each angle for annealing and cooling the glasses. The metal is wrought on two opposite sides, and on the other two they have their calcars, into which are made linnet-holes for the fire to come from the furnace, to bake the frit, and also to discharge the smoke. Fires are made in the arches to anneal the vessels, so that the whole process is done in one furnace. The materials with which the insides of these furnaces are constructed are not ordinary brick (which would soon melt down into glass, as would also all the softer stones,) but hard and sandy kinds, called by Imperatus "pyramachia." But when bricks are used, they should be formed of an earth which possesses in the highest degree the qualities of density and infusibility, for resisting the fire, which continues to act upon them, without cessation for a long time; as the fires in a glass-house are seldom suffered to go out, from the time when the furnace is first employed till it needs repair, and the interval may be two or three years; the walls of the furnace, for this reason, as well as the pots, are constructed chiefly of clay, mixed with sand, and other materials of a refractory kind, in due proportion. See *GLASS-pots*.

GLASS of lead, a glass made with the addition of a large quantity of lead, of great use in the art of making counterfeit gems. The method of making it is this: put a large quantity of lead into a potter's kiln, and keep it in a state of fusion with a moderate fire, till it is calcined to a grey loose powder: then spread it in the kiln, and give it a greater heat, continually stirring it to keep it from running into lumps; continue this several hours, till the powder becomes of a fair yellow; then take it out and sift it fine: this is called calcined lead.

Take of this calcined lead fifteen pounds, and crystalline, or other frit, twelve pounds; mix these as well as possible together; put them into a pot, and set them in the furnace for ten hours; then cast the whole, which will be now perfectly melted, into water; separate the loose lead from it, and return the metal into the pot; and after standing in

fusion twelve hours more, it will be fit to work. It is very tender and brittle, and must be worked with great care, taking it slowly out of the pot, and continually wetting the marble it is wrought upon. Neri.

It is well known, that cerufs, or white lead, minium, litharge, and all the other preparations and calces of lead, are easily fused by a moderate fire, and formed into a transparent glass of a deep yellow colour. But this glass is so penetrating and powerful a flux, that it is necessary to give it a greater consistence, in order to render it fit for use. With this view, two parts of calx of lead, *e. g.* minium, and other parts of sand, or powdered flints, may be put into a crucible of refractory clay, and baked into a compact body. Let this crucible, well closed with a luted lid, be placed in a melting furnace, and gradually heated, for an hour, or an hour and a half; and afterwards let the heat be increased, so as to obtain a complete fusion, and continued in that state for the same time: let this crucible remain to cool in the furnace, and when it is broken, a very transparent yellow-coloured glass will be found in it. Some add nitre and common salt to the above mixture, because these salts promote the fusion and the more equal distribution of the sand. This glass of lead has a considerable specific gravity, and its lowest part is always the heaviest. It is an important flux in the assays of ores to facilitate their scorifications.

Glass of lead is capable of all the colours of the gems in very great perfection. The methods of giving them are these: for green, take pulverine frit twenty pounds, lead calcined sixteen pounds; sift both the powders very fine; then melt them into a glass, separating the unmixed lead, by plunging the mass in water; after this return it into the pot, and add brass thrice calcined six ounces, and one pennyweight of crocus martis made with vinegar; put this in at six different times, always carefully mixing it together; let it finally settle an hour, then mix it together, and take a proof of it; when the colour is right, let it stand eight hours, and then work it. If instead of the calcined brass the same quantity of the caput mortuum of the vitriolum veneris be used, the green is yet much finer.

For topaze-colour take crystal frit fifteen pounds, calcined lead twelve pounds; mix them well together, by sifting the powders through a fine sieve; then set them in a furnace not too hot, and separate the superfluous unmixed lead, by casting the whole into water: repeat this twice; then add half gold yellow glass, and let them incorporate and purify, and they will be of the true and exact colour of the original topazes.

For sea-green, take crystal frit sixteen pounds, calcined lead ten pounds; mix and sift them together, and set them in a pot in a furnace: in twelve hours the whole will be melted; then cast it into water and separate it from the loose lead; put them into the furnace again for eight hours; then separate the loose lead by washing a second time, and return it to the pot for eight hours more. Neri. See GEMS.

GLASS, Painting in. The primitive manner of painting in glass was very simple, and of consequence very easy: it consisted in the mere arrangement of pieces of glass of different colours, in some sort of symmetry; and constituted a kind of what we call *Mosaic work*.

Afterwards, when they came to attempt more regular designs, and even to represent figures raised with all their shades, their whole address went no farther than to the drawing the contours of the figures in black, with water colours, and hatching the draperies, after the same manner, on glasses of the colour of the object intended to be painted. For the carnations, they chose glass of a bright red; upon which

they designed the principal lineaments of the face, &c. with black.

At last the taste for this sort of painting being considerably improved, and the art being found applicable to the adorning of churches, basilicas, &c. they found means of incorporating the colours with the glass itself, by exposing them to a proper degree of fire, after the colours had been laid on.

A French painter at Marseilles is said to have given the first notion hereof, upon going to Rome, under the pontificate of Julius II. But Albert Durer, and Lucas of Leyden, were the first that carried it to any height.

The colours used in painting on glass are very different from those used either in painting in oil, or water.

The *black* is made of two-thirds of flakes, or scales of iron, beaten up, and mixed with another third of roccaille, or little glass beads. *White*, with sand, or little white pebbles, calcined, pounded in a mortar, and afterwards ground on marble; with one fourth-part of salt-petre, added thereto, and the mixture calcined and pulverized over again: to which, when they are ready to use it, is added a little gypsum, or plaster of Paris well ground, &c. For *yellow*, they use leaf-silver ground, mixed up in a crucible, with sulphur or salt-petre; then well beaten and ground on a porphyry stone; and, at length, ground over again with nine times as much red ochre. *Red* is made of litharge of silver, and scales of iron, gum Arabic, ferretta, glass-beads, and blood-stone, nearly in equal quantities. This is one of the most difficult colours, and the preparation only to be learned by experience. *Green* is made of *æs uftum*, one ounce; as much black lead, and four ounces of white sand, incorporated by the fire. After calcination, they add a fourth part of salt-petre: after a second calcination, a sixth part more: after which they make a third coction before it is used. *Azure*, *purple*, and *violets*, are prepared like green, only leaving out the *æs uftum*, and in the lieu thereof using sulphur for azure; perigueux for purple; and both these drugs for violet. *Carnations* are made of ferretta and roccaille. And lastly, colours for the hair, trunks of trees, &c. are made of ferretta, roccaille, &c.

This account of colours we have from M. Felibien's excellent work *Des Principes d'Architecture*, &c. though it must be owned, that all the painters on glass do not use them; there being few artists of that kind but have invented their own particular ones, whereof they usually make great secrets. But this is certain, that these above described are sufficient for the best paintings of all sorts; provided the person has but the skill to manage them.

In the windows of divers ancient churches, chapels, colleges, &c. we meet with the most beautiful and lively colours imaginable; such as far exceed any used among us: but it is not that the secret of making those colours is lost; but that the moderns would not go to the expence of them; nor take all the necessary pains; because this sort of painting is not now so much esteemed as formerly.

Mr. Walpole, in his *Anecdotes of painting in England*, has traced the history of this art from the reformation, when misguided zeal destroyed most of the monuments of it in our churches, through a series of professors to the present time. Among the later proficientes in this art were Isaac Oliver, who painted the windows at Christ-church, Oxford, in 1700; William Price, who in the same year painted the windows in Merton chapel; William Price, the son, to whose art we owe the windows at Queen's, New-college, and Maudlin, of whom Mr. Walpole says, that his colours are fine, his drawing

good, and his taste in ornaments and Mosaic far superior to any of his predecessors, and equal to the antique. In 1761, Mr. Paterfon, an auctioneer late of Essex-house in London, exhibited the two first auctions of painted glass imported from Flanders; and undertook also to establish a manufacture of painted glass: several of the pieces of this ingenious artist exhibited colours vying in perfection with the old paintings.

Those beautiful works, among the painters in glass, which were made in the glass-house, were of two kinds: in some, the colour was diffused through the whole body of glass; in others, which were the more common, the colour was only on one side, scarce penetrating within the substance above one-third of a line; though this was, more or less, according to the nature of the colour; the yellow being always found to enter the deepest.

These last, though not so strong and beautiful as the former, were of more advantage to the workmen; because, on the same glass, though already coloured, they could shew other kinds of colours, where there was occasion to embroider draperies, enrich them with foliages, or represent other ornaments of gold, silver, &c.

In order to this, they made use of emery; grinding, or wearing down the surface of the glass, till such time as they were got through the colour, to the clear glass: this done, they applied the proper colours on the other side of the glass. By this means the new colours were prevented from running and mixing among the former, when the glasses came to be exposed to the fire, as will hereafter be shewn.

When the intended ornaments were to appear white, or silvered, they contented themselves to bare the glass of its colour with emery, without applying any new colour at all; and it was in this manner that they wrought the lights and heightenings on all kinds of colours.

The painting with vitreous colours on glass depends entirely on the same principles as painting in enamel; and the manner of executing it is likewise the same; except that in this the transparency of the colours being indispensibly requisite, no substances can be used to form them but such as vitrify perfectly: and, therefore, the great object is to find a set of colours, which are composed of such substances, as, by the admixture of other bodies, may promote their vitrification and fusion; are capable of being converted into glass; and melting, in that state, with less heat than is sufficient to melt such other kinds of glass as may be chosen for the ground or body to be painted; to temper these colours, so as to make them proper to be worked with a pencil; and to burn or reduce them by heat, to a due state of fusion, without injuring or melting the glass which constitutes the body painted. The first thing to be done, in order to paint on glass, in the modern way, is to design, and even colour, the whole subject on paper. Then they make choice of pieces of glass proper to receive the several parts, and proceed to divide or distribute the design itself, or the paper it is drawn on, into pieces suitable to those of glass; having always a view that the glasses may join in the contours of the figures, and the folds of the draperies; that the carnations and other finer parts may not be damaged by the lead wherewith the pieces are to be joined together.

The distribution being made, they mark all the glasses, as well as papers, with letters, or numbers, that they may be known again; which done, applying each part of the design on the glass intended for it, they copy or transfer the design upon this glass, with the black colour,

diluted in gum-water; by tracing and following all the lines and strokes, as they appear through the glass, with the point of a pencil.

When these first strokes are well dried, which happens in about two days, the work being only in black and white, they give it a slight wash over, with urine, gum Arabic, and a little black; and this several times repeated, according as the shades are desired to be heightened; with this precaution, never to apply a new wash, till the former is sufficiently dried. This done, the lights and risings are given, by rubbing off the colour in the respective places, with a wooden point or the handle of the pencil.

As to the other colours above-mentioned, they are used with gum-water, much as in painting in miniature; taking care to apply them lightly, for fear of effacing the outlines of the design; or even, for the greater security, to apply them on the other side, especially yellow, which is very pernicious to other colours, by blending therewith.

And here too, as in pieces of black and white, particular regard must be always had, not to lay colour on colour, or lay on a new lay, till such time as the former are well dried. It may be added, that the yellow is the only colour that penetrates through the glass, and incorporates therewith by the fire; the rest, and particularly the blue, which is very difficult to use, remaining on the surface, or at least entering very little. When the painting of all the pieces is finished, they are carried to the furnace or oven, to anneal or bake the colours. The furnace here used is small, built of brick, from eighteen to thirty inches square: at six inches from the bottom is an aperture, to put in the fuel, and maintain the fire. Over this aperture is a grate, made of three square bars of iron, which traverse the furnace, and divide it into two parts. Two inches above this partition is another little aperture, through which they take out pieces, to examine how the coction goes forward.

On the grate is placed a square earthen pan, six or seven inches deep; and five or six inches less, every way, than the perimeter of the furnace. On one side hereof is a little aperture, through which to make the trials, placed directly opposite to that of the furnaces destined for the same end.

In this pan are the pieces of glass to be placed in the following manner; first, the bottom of the pan is covered with three strata, or layers of quicklime, pulverized; those strata being separated by two others, of old broken glass: the design whereof is to secure the painted glass from the too intense heat of the fire. This done, the glasses are laid horizontally on the last, or uppermost, layer of lime.

The first row of glass, they cover over with a layer of the same powder an inch deep; and over this they lay another range of glasses: and thus alternately, till the pan is quite full; taking care that the whole heap always ends with a layer of the lime-powder.

The pan thus prepared, they cover up the furnace with tiles, on a square table of earthen-ware, closely luted all round; only having five little apertures, one at each corner, and another in the middle, to serve as chimnies.

Things thus disposed, there remains nothing but to give the fire to the work. The fire for the two first hours must be very moderate; and must be increased in proportion as the coction advances, for the space of ten or twelve hours; in which time it is usually completed. At last,

the fire, which at first was only of charcoal, is to be of dry wood: so that the flame covers the whole pan, and even issues out at the chimnies.

During the last hours, they make assays from time to time, by taking out pieces laid for that purpose, through the little aperture of the furnace, and pan, to see whether the yellow be perfect, and the other colours in good order. When the annealing is thought sufficient, they proceed with great haste to extinguish the fire, which otherwise would soon burn the colours, and break the glasses. See PAINTING.

GLASS, *painting on, by means of paints.* See BACK-painting.

GLASS, *polishing of.* See POLISHING and GRINDING.

GLASS-porcelain, the name given by many to a modern invention of imitating the china-ware with glass. The method given by M. Reaumur, who was the first that carried the attempt to any degree of perfection, is delivered by that gentleman in the Memoirs of the Academy of Sciences of Paris, to this effect. This change of glass was first taken notice of by Neumann, who, in distilling milk in a glass retort, observed, that the bottom of the vessel acquired the appearance of porcelain, which he attributes to the fine white earthy matter of the milk forced into the glass by heat. Neum. Chem. Works by Dr. Lewis, p. 571.

The mixing of glass reduced to powder, with other less easily vitrifiable substances for forming a paste, to be afterwards made into a sort of a porcelain, has been a contrivance long practised, but it is very troublesome, and the result subject to many faults; but this new ware is made of glass alone, and that with much less trouble, and without the reducing it to powder. By this art, vessels of glass are changed into vessels of a sort of porcelain, without altering their form, and the meanest glass made only of sand, lime, and saline ashes, serves as well as the best for that purpose: our common coarse green quart-bottles, or the great bell glasses with which gardeners cover their melons, &c. being by this means changeable into a beautiful white sort of porcelain ware; and this is to be done in so easy a manner, and with so small expence, that it requires no more trouble or charge, than that of baking a common vessel of our coarse earthen-ware; and for this reason the vessels of this sort of ware may be afforded extremely cheap.

It is very certain, that all porcelain ware is a substance in the state of semi-vitrification: and in order to bring glass, which is a wholly vitrified substance, into the condition of porcelain, there requires no more than to reduce it to a less perfectly vitrified state.

The question which would naturally be started on this occasion, is, whether it be possible to reduce glass to a less vitrified state, it having already undergone what is esteemed the last change by fire. But when we consider, that the mass of antimony, the vitrifications of many of the metals, as the glass of lead, and the counterfeit gems coloured by the metals, are more or less easily reduced again by chemistry to metals, &c. the reducing of sand, flints, &c. after they are vitrified, at least a little way back toward their native or pristine state, may appear not wholly unpracticable, and the attempts which M. Reaumur made on this occasion, were what gave him the first hints of the glass-porcelain; called from his name "Reaumur's porcelain."

The method of making it is this. The glass vessels to be converted into porcelain are to be put into a large earthen vessel, such as the common fine earthen dishes are baked in, or into sufficiently large crucibles; the vessels are to be filled with a mixture of fine white sand, and of fine gypsum or plaster-stone burnt into what is called plaster of Paris, and

all the interstices are to be filled up with the same powder, so that the glass vessels may no where touch either one another, or the sides of the vessel they are baked in. The vessel is to be then covered down and luted, and the fire does the rest of the work; for this is only to be put into a common potter's furnace, and when it has stood there the usual time for the baking of the other vessels, it is to be taken out, and the whole contents will be found no longer glass, but converted into a white opaque substance, which is a very elegant porcelain, and has almost the properties of that of China. Memoirs Acad. Sciences Par. 1739.

The powder which has served once, will do again as well as fresh, and that for a great many times: nay, it seems, ever so often. The cause of this transformation, says Macquer, is probably that the vitriolic acid of the gypsum quits its basis of calcareous earth, and unites with the alkaline salt and saline earth of the glass, with which it forms a kind of salt or selenites, differing from the calcareous selenites, by the interposition of which matter the glass acquires the qualities of porcelain. Dr. Lewis, from a variety of experiments on the nature and qualities, and method of producing this porcelain, has deduced the following conclusions: 1. Green glass cemented with white sand received no change in a heat below ignition: in a low red-heat, the change proceeded very slowly; but in a strong red-heat, approaching to whiteness, the thickest pieces of glass bottles were thoroughly changed in three hours. 2. The glass sustained the following progression of changes. Its surface first became blue; its transparency was diminished, and when held between the light and the eye, it appeared of a yellowish hue: afterwards it was changed a little way on both sides into a white substance, externally still blueish: and as this change advanced still further and farther within the glass, the colour of the vitreous part in the middle approached nearer to yellow: the white coat was of a fine fibrous texture, and the fibres were disposed nearly parallel to one another, and transverse to the thickness of the piece: by degrees the glass became throughout white and fibrous, the external blueishness at the same time going off, and being succeeded by a dull whitish or dun colour: by a still longer continuance in the fire, the fibres were changed gradually from the external to the internal part, and converted into grains; and the texture then was not unlike that of common porcelain. The grains, at first fine and somewhat glossy, appeared afterwards larger and duller, and at length the substance of the glass became porous and friable, like a mass of white sand slightly cohering. 3. Concerning the qualities of the converted glass Dr. Lewis observes, that the whiteness of the internal part was not inferior to that of porcelain, but that its surface was the least beautiful; that the thick pieces were quite opaque, and that several thin pieces were semi-transparent: that while it remained in a fibrous state, its hardness became greater than that of glass, or of the common kinds of porcelain; it was capable of sustaining sudden changes of heat and cold better than any porcelain; and in a moderate white heat, it was fusible into a substance not fibrous, but vitreous and smooth, like white enamel: that when its texture had been coarsely granulated, it was now much softer and unfusible; and, lastly, that when some coarsely granulated unfusible pieces which, with the continuance of a moderate heat, would have become porous and friable, were suddenly exposed to an intense fire, they were rendered remarkably more compact than before; the solidity of some of them being superior to that of any other ware. 4. No differences appeared in the internal colour, hardness, texture, or the regular succession of changes, from the use of different cementing substances:

though in external appearances the differences were considerable. All the pieces which had been surrounded with charcoal or with foot were externally of a deep black colour, which did not disappear by exposure to a strong fire during an hour, with free access of air. Coloured clays and sands communicated different shades of a brown colour; and white earths gave whitish, greyish, or brownish tinges. White sand, calcined flints, and gypsum, gave in general the greatest whiteness, and tobacco-pipe clay the greatest glossiness and brightness. Glasses composed of earths without alkaline salt, glass of lead, flint-glass, crown-glass, looking-glass plates, a glass prepared with calcined flints and a fixed alkaline salt, and even green glass which had been fused together with a ninth part of alkaline salt, suffered none of the above alterations by cementation. Green bottle-glass and common window-glass were most susceptible of these alterations. 6. The changes produced by cementation could not proceed from any absorption of matter from the cementing substance; because no increase of weight was given, and because the same changes were produced upon a piece of glass merely by heat, without any cementing substance. See *Com. Phil. Techn.* p. 230—255.

Mr. Gregory Watt, in his valuable paper on basalt (*Phil. Trans.* for 1804, cited by Aikin,) alleges this porcellaneous change of glass as an illustration of his important principle, *viz.* "that bodies whose fibres have a natural tendency to a crystalline arrangement, or a polarity, when vitrified by a sufficient heat and cooled hastily in the vitreous state, are able subsequently to return to their natural crystalline arrangement of fibre, when exposed to a heat merely sufficient to soften the texture, though not enough for fusion. This, in the instance of basalt, he shews by the singular crystallizations formed in the cells of fused basalt, long after it had lost the liquidity of fusion. The circumstance of no material change occurring in the weight of glass by this conversion into the fibrous state, shews incontestably that it cannot be owing either to any thing gained during the process, nor to any material loss of the alkali; and this is also rendered manifest by its return to the vitreous state and vitreous qualities when again melted. This too may again be porcellanized in the same way, and again be melted into glass, and so on alternately." See **PORCELAIN**.

GLASS-pots, the vessels in the glass manufacture used for melting the glass. Those for the white glass works are made of a tobacco-pipe clay, brought from the Isle of Wight, which is first well washed, then calcined, and afterwards ground to a fine powder in a mill; which being mixt with water, is then trod with the bare feet till it is of a proper consistence, to mould with the hands into the proper shape of the vessels. When these are thus made, they are afterwards annealed over the furnace. Those for the green-glass work are made of the nonsuch, and another sort of clay from Staffordshire; they make these so large as to hold three or four hundred weight of metal. And besides these, they have a small sort called piling pots, which they set upon the larger, and which contain a finer and more nice metal fit for the nicest works. **Neri**.

The clay that is used for this purpose should be of the purest and most refractory kind, and well cleansed from all sandy, ferruginous, and pyritous matters; and to this it will be proper to add ground crucibles, white sand, calcined flints duly levigated, or a certain proportion of the same clay baked, and pounded not very finely. The quantity of baked clay that ought to be mixed with the crude clay, to prevent the pots from cracking when dried, or exposed to a great heat, is not absolutely determined, but depends on

the quality of the crude clay, which is more or less fat. **M. D'Antic**, in a memoir on this subject, proposes the following method of ascertaining it: the burnt and crude clay, being mixed in different proportions, should be formed into cakes, one inch thick, and four inches long and wide. Let these cakes be slowly dried, and exposed to a violent heat, till they become as hard and as much contracted as possible, and in this state be examined; and the cake, he says, which has suffered a diminution of its bulk equal only to an eighteenth part, is made of the best proportions. He observes, in general, that most clays require that the proportion of the burnt should be to the fresh as four to five.

It is of great importance that the material of which the pots are made should be carefully selected, as they are exposed to the action of a very fierce fire, and also to the solvent activity of the glass with its powerful fluxes. They should also be made very thick and strong, as they are intended to last for many months. When finished, they are placed in a warm room in order to discharge their moisture, and any small fissures arising from the unequal shrinking of the clay are closed by gently beating with a mallet. They are afterwards gradually heated in a small oven, constructed for this purpose, and slowly brought to a red heat; and after remaining for some time in this state, they are removed to the furnace, and fixed down in their places by fire-clay. Here, on account of a further shrinking, they remain for a day or two before they are fit for receiving the glass materials. Pots of this kind are said to last, at an average, about a year.

GLASS Tubes are of various lengths, diameters, and forms, according to the purposes to which they are applied. These are often formed with the lamp and blow-pipe, in the manner described under the article **LAMP-blowers**. In this way tubes are sealed hermetically (see **HERMETICAL Seal**), tubes are bent, others are joined, bulbs are annexed to tubes for thermometers, &c., and glass is drawn out into threads.

It has been observed, that glass tubes laid before the fire in an horizontal position, and with their extremities supported, have had a rotatory motion about their axes; and also a progressive motion towards the fire, even when their supports are inclined from the fire, so that the tubes will move a little upwards. See *Phil. Trans.* N° 476. § 1.

When the progressive motion of the tube is stopped by any obstacle, its motion about its axis will still continue. When the tubes are placed in a nearly upright posture leaning to the right hand, the motion will be from east to west; but if they lean to the left, the motion will be from west to east; when the nearer they are placed to the perfectly upright posture, the less the motion will be either way.

If the tube be placed horizontally on a glass plane, the fragment, for instance, of coach window-glass, instead of moving towards the fire, will move from it, and about its axis, in a contrary direction to what it had done before. Nay, it will recede from the fire and move a little upwards, when the plane inclines towards the fire.

Neither the draught of air up the chimney, nor attraction or repulsion, are the cause of these phenomena. It seems rather owing to the swelling of the tube towards the fire; for allowing such swelling, gravity must pull the tube down, when supported near its extremities horizontally; and a fresh part being exposed to the fire and swelling out again, must fall down again, and so on successively; which will produce a rotatory motion towards the fire.

If the tube be supported by two other tubes, and these be brought near to each other, and to the centre of the supported tube, then its parts hanging over on each side, being larger than the part which lies between the supporters, will,

by their weight, pull downwards, and consequently force the middle part, resting upon its two props, upwards: and being less advanced towards the fire, as being less heated, will, by their oblique situation, pull the middle part backwards also from the fire, which will cause a rotatory regressive motion, quite contrary to what the tube had when supported near its extremities. And when a single tube lies inclining opposite to the fire, either to the right hand or to the left, out of a plane perpendicular to the surface of the fire, gravity will not permit the curved part to rest, but pull it down till it coincides with a plane perpendicular to the horizon; and consequently, as new curves are generated, new motions will be so too; that is, the tube will be made to move about its axis, with this difference, when the tube inclines to the right hand, the motion will be from east to west; when to the left hand, from west to east. The justness of this reasoning is made manifest, by bending a wire, and supporting it first near its extremities, then near its centre on each side, afterwards inclining it to the right and to the left; the bending in every case representing the curved part of the tube next the fire. This solution of the phenomena is rendered the more probable from hence, that when four supporters were made use of, one at each extremity, and two near the middle, there was no motion at all, either backward or forward. Nor does the increase of contact hinder the motion, because the plate of glass was so broad as to have a much greater contact with the tube, and yet both the rotatory and regressive motions were manifest.

These experiments succeeded best with tubes about twenty or twenty-two inches long; the diameter about one-tenth of an inch: and they had in each a pretty strong pin fixed in cork, for an axis to roll with on the supporting tubes. Phil. Trans. N° 476.

GLASS receivers, how to cement the cracks of. See CEMENT and RECEIVER.

GLASS, how to take the impression of antique gems in. See GEM.

The property which glass possesses in common with other substances of being expanded by heat, and contracted by cold, was long ago observed and evinced by Mr. Hook. See Birch's Hist. of the Royal Society, vol. i. p. 411. See THERMOMETER.

GLASS, Laws relating to. No glass shall be imported into Ireland, other than the manufacture of Great Britain, on pain of forfeiting the same, and ship, and 10s. a pound. 19 G. II. c. 12. If any foreign glass shall be landed or unshipped before entry and payment of the duties, or without warrant from the proper officer, the same shall be forfeited, or its value; and the master or other person having command of the vessel, and every other person concerned in such landing or unshipping, shall forfeit 100l. 17 G. III. c. 39. And by 38 G. III. c. 33. for preventing the fraudulent importation of glass, every package containing any plate or plates of glass unframed, being *plate, crown, or sheet glass*, which shall be imported, or brought into this kingdom for exportation, shall be marked on the outside in Roman letters four inches long at least, with the word GLASS, on pain of forfeiture, together with the package, and all goods contained in it. The master of the vessel importing such package, shall, in reporting his cargo, express every such package of glass, on pain of forfeiting the same, and also 100l. Nor

shall any such package be imported, which shall not contain 500 weight, on pain of forfeiture; but not extending to any plate of glass 60 inches in length or upwards, on account of the package not being marked. By 43 G. III. c. 69. For every 100 weight of materials, &c. that shall be made use of in Great Britain for the making of *plate or flint glass*, or *enamel, stained, or paste glass*, or *phial glass*, shall be paid by the maker thereof 1l. 12s. 8d.; for every hundred weight of materials used in making *spread window glass*, commonly called *broad glass*, 8s. 2d.; for every hundred weight of materials used for making all other *window glass* (not being spread glass), whether flashed, or otherwise manufactured, commonly called *crown glass*, or *German sheet glass*, 1l. 4s. 6d.; for every hundred weight of materials used in making *common bottles* (not being phials), and of vessels used in *chemical laboratories*, and of *garden glasses*, and of all other vessels or utensils made of common bottle metal, 4s. 1d.; and for every hundred weight of plate glass, and of all other glass manufactures, which shall be imported into Great Britain, the same not being flasks, in which wine or oil is imported, nor foreign green glass bottles, nor Irish glass, or glass manufactures imported directly from Ireland, to be paid by the importer before the landing thereof, 2l. 2s. And any glass-maker shall take out a licence, for which he shall pay 10l., to be renewed annually ten days at least before the end of the year, on the penalty of 50l. 24 G. III. c. 41. 43 G. III. c. 69. The place of making glass shall be entered, before the commencement of manufacture, and all work-houses, furnaces, pots, annealing arches, &c. &c. on pain of forfeiting 200l. 19 G. II. c. 12. 17 G. III. c. 39. 35 G. III. c. 114. Officers may enter and survey, and mark pots; and any person counterfeiting or altering such mark, or conniving at its being done, shall forfeit 500l.; or defacing, or causing to be defaced or obliterated such mark, incurs a forfeiture of 200l. 35 G. III. c. 114. Notice of beginning to work shall be given in writing, on pain of forfeiting 20l. 19 G. II. c. 12. And notice of filling every pot shall be given twelve hours before the operation is begun, on pain of 50l. 19 G. II. c. 12. 17 G. III. c. 39. Annealing arches are to be made of a certain form, and numbered, on pain of forfeiting 100l. Annealing arches are to be locked, except at certain times; and breaking such lock, &c. incurs a forfeiture of 200l. 35 G. III. c. 114. The same act comprehends several other provisions, enforced by certain penalties. Bottles are not to be removed till they are weighed, (penalty 100l.) which are to be kept separate from those that are unweighed, on pain of forfeiting 50l. No phials, &c. are to be made in places entered for making common glass bottles, on pain of forfeiting 200l. Entry shall be made of the glass manufactured every month within the bills, and elsewhere every six weeks, on pain of 20l. The maker, within the bills, shall, in four weeks, and elsewhere in six weeks after entry, pay off the duties, on pain of double duty. If glass, shipped for exportation, shall be re-landed, it shall be forfeited, and every person concerned therein shall forfeit 100l. 17 G. III. c. 39. For the drawbacks on exportation of glass, see 43 G. III. c. 69. Obstructing officers in securing the duties incurs a forfeiture of 50l. 19 G. II. c. 12. 17 G. III. c. 39. Penalties are appropriated, half to the use of the king, and half to him that shall sue.

Glauber

GLAUBER, JOHN RODOLPH, in *Biography*, a celebrated chemist of Amsterdam, who was esteemed the Paracelsus of his age, was born in Germany in the beginning of the sixteenth century. He travelled much in the pursuit of chemical knowledge, and collected many secret processes; and his experiments contributed to throw much light on the composition and analysis of the metals, inflammable substances, and salts. In fact he passed the greater part of his life in the laboratory. He did not always see the proper application of his own experiments, and vainly fancied that he had discovered the panacea, and the philosopher's stone, which were at that time objects of pursuit: and the disappointment of many persons, who had been seduced by his promises, contributed to bring the art of chemistry into contempt. His theory is full of obscurity; but his practice has perhaps been misrepresented by those who listened to his vain and pompous pretensions; and who accuse him of a dishonourable traffick, in first selling his secrets to chemists at an enormous price, of again disposing of them to other persons, and lastly, of making them public in order to extend his reputation. Glauber published about twenty treatises; in some of which he appears in the character of physician, in others in that of an adept or metallurgist; in the latter he most particularly excelled. However, it would be unjust not to give him the praise of acuteness of mind, of facility and address in the prosecution of his experiments, and of extensive chemical knowledge. He was the inventor of a salt, which to this day retains his name in the shops of our apothecaries. The works of Glauber have appeared in different languages; the majority of editions are in German, some in Latin, and others in French. A collection of the whole in Latin was published at Frankfort in 1658, in 8vo. and again 1659 in 4to. An English translation was published by Christopher Pack, London, 1689, in folio. Eloy. Dict. Hist.

GLAUBER Salt, *native* or *natural*, in *Mineralogy*, the sulphat of soda of chemists, was discovered by baron Born in the salt mines of Upper Austria; after which Monnet Volta, Suckow, Gmelin, Breislak, Pallas, and others have added to the list of the localities of this saline substance, which is more frequently found in a native state than has been supposed by some writers. It generally occurs as mealy efflorescence; sometimes massive, seldom stalactitical or crystallized: in which latter case the crystals

are described as acicular and as six-sided prisms, more or less flatly acuminate by three planes, set on the lateral edges, or sometimes on the lateral planes: they are shining: their internal lustre is vitreous. Fracture of the crystals small conchoidal. It varies from transparent to opaque according to its freshness. It is brittle. Its taste is a mixture of salt and bitter. Besides in the above forms, it occurs also, and most frequently, dissolved in certain mineral waters, in the neighbourhood of salt mines and salt lakes, where also the efflorescence is mostly found on moorish ground, sand stone, marble slate, and new walls. For the chemical character of this salt, see SONA, *Sulphat of*.

Brongniart has given the most complete list of the localities of Glauber salt. In solution it occurs in the waters of several lakes of Austria and Lower Hungary, especially in that of Neusiedel, between the counties of Oedenburg and Wieselburg. It is met with in Switzerland; in Spain, round a source in the neighbourhood of Aranjuez, and near Vacia-Madrid, as efflorescence, at the bottom of a ravine: the source which issues from the ravine contains a great proportion of this salt. Also the water of the Tagus is said to hold it in solution. In France it has been found near Grenoble. The steep sides of the Solfatara of Pouzzole yield this salt, in one place, on the north side. It is common in the lakes of Siberia; and it has been observed that the bottom of the lake Guniskoi, between Toion and Ilynskoy, is covered with a crust of Glauber salt as soon as the temperature is below the freezing point. Pallas tells us that the apothecaries of Orenburg annually collect a quantity of this salt, which is deposited in autumn at the bottom of a lake between the Tobol and Mioss. It is also found in a lake near Gourief; in another between Utoiska and Miniuskaia, in the neighbourhood of Enissey; likewise at the foot and in the middle of the chains of the Ural mountains, near Tsheliabinsk: in the last of these places, the salt issues in the spring season out of the earth in the form of efflorescence or froth. The clayey soil of that neighbourhood does not contain any Glauber salt; whence this is supposed to be formed, in the same manner as salt-petre is, at the surface of the earth, and by the action of the atmosphere. Lastly, this salt is also obtained from the alum-slate of Duttweiler, near Saarbrück, in the department of la Sarre, and from the aluminiferous waters of Freyenwalde, in Brandenburg.

Glazing

GLAZING. The Roman method of glazing some of their urns might give our workmen a hint toward a method greatly superior to any thing now in practice for the glazing of earthen-ware. There is a sort of red urns found in Yorkshire, which are, instead of glazing, covered all over inside and out with a fine coral-coloured varnish, that gives them a beauty, which no earthen-ware of our times can attain; and is not only far more durable than our way of doing it with lead, which is apt to crack and fly, both with wet and with heat, but far more safe and wholesome; and being well known to be a vapourable metal, and its fumes very noxious, there is great reason to suspect that it must be unwholesome when brought to the fire. This ancient glazing seems to have been done either by the brush, or else by dipping, for both the inside and outside are varnished with equal regularity; and something may be guessed at as to the materials they used in it, from what Pliny has left us. This author occasionally observes, that such earthen-ware as was painted with bitumen never lost its beauty; and afterwards, that it was a custom to cover over whole statues with this sort of glazing, which he observes did not only make a smooth coat, but sunk into the matter of the stone or earth, and therefore this could not be likely to crack and fly off like our lead-coats on plates, &c. which is merely a crust laid over them. Hook's *Philos. Collect.* p. 89.

A common glazing for any kind of earthen-ware may be made of white sand forty pounds, of red-lead twenty pounds, of pearl-ashes twenty pounds, and of common salt twelve pounds. Powder the sand by grinding it, and then add it to the other ingredients and grind them together: after which calcine them for some time with a moderate heat, and when the mixture is cold, pound it to powder; and when wanted for use, temper it with water. The proportion of these ingredients may be occasionally

varied. We may observe, in general, that lead ought to be excluded from the composition of glazings, and other fluxes substituted in its stead. See *COLICA Dammoniorum*.

A transparent glazing may be prepared, without lead, by calcining forty pounds of white sand, twenty-five pounds of pearl-ashes, and fifteen pounds of common salt; and proceeding as before: and a more perfect transparent glazing may be made of sand forty pounds, of wood-ashes perfectly burnt, fifty pounds, of pearl-ashes ten pounds, and of common salt twelve pounds. The following recipes are taken, for the most part, from Kunckel, who says that they are the true glazings used at Delft, and other Dutch manufactories.

GLAZING, Black, is made of eight parts of red-lead, iron filings three, copper-ashes three, and zaffre two measures. This, when melted, will make a brown black; and if you want it blacker, add more zaffer to it.

GLAZING, Blue, is thus prepared: take lead-ashes, or red-lead, one pound, clear sand, or powdered flints, two pounds, common salt two pounds, white calcined tartar one pound, Venice or other glass half a pound, zaffer half a pound; mix them well together, and melt them for several times, quenching them always in cold water. If you would have it fine and good, it will be proper to put the mixture into a glass furnace for a day or two.

Another blue glazing may be formed of one pound of tartar, a quarter of a pound of red-lead, half an ounce of zaffer, and a quarter of a pound of powdered flints, which are to be fused and managed as in the last recipe. Or, take two pounds of calcined lead and tin, add five pounds of common salt, five pounds of powdered flints, and of zaffer, tartar, and Venetian glass, each one pound. Calcine and fuse the mixture as before.

Or, again, take of red-lead one part, of sand three parts, and of zaffer one part. For a violet blue glazing, take four

ounces of tartar, two ounces of red-lead, five ounces of powdered flints, and half a dram of manganese.

GLAZING, Brown, is made of red-lead and flints, of each fourteen parts, and of manganese two parts, fused: or, of red-lead twelve parts, and manganese one part, fused. A brown glazing, to be laid on a white ground, may be made of manganese two parts, and of red-lead and white glass, of each one part, twice fused.

GLAZING, Flesh-coloured, is made of twelve parts of lead-ashes, and one of white glass.

GLAZING, Gold-coloured. To make gold-coloured glazing, take of litharge three parts; of sand, or calcined flint, one part: pound, and mix these very well together; then run them into a yellow glass with a strong fire. Pound this glass, and grind it into a subtile powder, which moisten with a well saturated solution of silver; make it into a paste, which put into a crucible, and cover it with a cover. Give at first a gentle degree of fire; then increase it, and continue it till you have a glass, which will be green. Pound this glass again, and grind it to a fine powder; moisten this powder with some beer, so that by means of an hair pencil you may apply it upon the vessels, or any piece of earthen ware. The vessels that are painted or covered over with this glazing, must be first well heated, then put under a muffle; and as soon as the glass runs, you must smother them, by holding them over burning vegetables, and take out the vessels. Mr. Heinsius of Petersburg, who sent this receipt to the Royal Society, uses the words *afflare debes fumum*, which is rendered *smother them*, in the Transactions. Phil. Trans. N 465. § 6.

Kunkel gives several preparations for a gold-coloured yellow glazing. This may be produced by fusing a mixture of three parts of red-lead, two parts of antimony, and one part of saffron of Mars; by again melting the powdered mass, and repeating the operation four times; or, by fusing four or five times a composition of red-lead and antimony, of each an ounce, and of scales of iron half an ounce: or by calcining and fusing together eight parts of red-lead, six parts of flints, one part of yellow ochre, one part of antimony, and one part of white glass. A transparent gold-coloured glazing may be obtained by twice fusing red-lead and white-flints, of each twelve parts, and of filings of iron one part.

GLAZING, Green, may be prepared of eight parts of litharge, or red-lead, eight parts of Venice glass, four parts of brass-dust, or filings of copper; or, of ten parts of litharge, twelve of flints or pebble, and one of *as ustum*, or copper-ashes.

A fine green glazing may be produced by using one part of the Bohemian granate, one part of filings of copper, one part of red-lead, and one part of Venetian glass; or by fusing one part of white glass, the same quantity of red-lead, and also of filings of copper; powdering the mass, and adding one part of Bohemian granate to two parts of this powder. A fine green may be obtained by mixing and grinding together any of the yellow glazings with equal quantities of the blue glazings; and all the shades and tints of green will be had by varying the proportion of the one to the other, and by the choice of the kind of yellow and blue.

GLAZING, Iron-coloured, is prepared of fifteen parts of lead-ashes, or red-lead, fourteen of white sand, or flints, and five of calcined copper. This mixture is to be calcined and fused.

GLAZING, Liver-coloured, is prepared of twelve parts of litharge, eight of salt, six of pebble or flint; and one of manganese.

GLAZING, Purple-brown, consists of lead-ashes fifteen parts, clear-sand, or powdered flints, eighteen parts, manganese one part, and white glass fifteen measures; to which some add one measure of zaffer.

GLAZING, Red, is made of antimony three pounds, litharge, or red-lead, three, and rust of iron, one; grind them to a fine powder. Or take two pounds of antimony, three of red-lead, and one of calcined saffron of Mars, and proceed as before.

GLAZING, Sea-green, is made of five pounds of lead ashes, one pound of tin-ashes, three pounds of flint, three quarters of a pound of salt, half a pound of tartar, and half a pound of copper dust.

GLAZING, White. A fine white glazing for earthen-ware is thus prepared: Take two pounds of lead, and one of tin; calcine them to ashes: of this take two parts, calcined flint, white sand, or broken white glass, one part, and salt one part: mix them well together, and melt them into a cake for use. The trouble of calcining the tin and lead may be prevented, by procuring them in a proper state.

The white glazing for common ware is made of forty pounds of clear sand, seventy-five pounds of litharge, or lead-ashes, twenty-six of pot-ashes, and ten pounds of salt: these are three times melted into a cake, quenching it each time in clear cold water. Or, it may be made of fifty pounds of clean sand, seventy of lead-ashes, thirty of wood-ashes, and twelve of salt.

A very fine white glazing may be obtained by calcining two parts of lead, and one part of tin; and taking one part of this mass, and of flints and common salt, of each one part, and fusing the mixture. See *DELFT-ware*.

A white glazing may be prepared by mixing one hundred pounds of masticot, sixty-pounds of red-lead, twenty pounds of calcined tin or putty, and ten pounds of common salt; and calcining and powdering the mixture several times.

GLAZING, Yellow, is prepared of red-lead, three pounds; calcined antimony and tin, of each two pounds: or, according to some, of equal quantities of the three ingredients. These must be melted into a cake, then ground fine; and this operation repeated several times: or, it may be made of fifteen parts of lead-ore, three parts of litharge of silver, and fifteen parts of sand.

A fine yellow glazing may be procured by mixing five parts of red-lead, two parts of powdered brick, one part of sand, one part of the white glazings, and two parts of antimony, calcining the mixture and then fusing it. Or, take four parts of white glass, one part of antimony, three parts of red-lead and one part of iron scales, and fuse the mixture: or, fuse sixteen parts of flints, one part of iron-filings, and twenty-four parts of litharge. A light yellow glazing may be produced with ten parts of red-lead, three parts of antimony, and three of glass, and two parts of calcined tin. See *Gold-coloured GLAZING*.

GLAZING, Citron-yellow, is made of six parts of red-lead, seven parts of fine red brick-dust, and two parts of antimony. This mixture must be calcined day and night for the space of four days, in the ash-hole of a glass-house furnace, and at last urged to fusion.

GLAZING of Delft-ware. See *DELFT-ware*.

GLAZING of Porcelain. See *PORCELAIN*.

GLAZING of Stone-ware, and Queen's ware. See *POTTERY*.

GLAZING for Tobacco Pipes. See *TOBACCO-PIPES*.

GLAZING, in Painting, a term of the art, expressive of a peculiar mode or variety in the practice of it. It consists in laying a transparent colour, made very thin by a great quantity of oil, or other vehicle, over a solid body of opaque

colour; and its intent is, to give a greater degree of clearness and brilliancy to the colour produced by this process, than can be obtained by mixing together in substance the two colours thus employed. In this mode their hues are blended, without disparagement of each other; whereas, in mixing them in the ordinary way, a certain diminution of their brilliancy takes place, produced by the dissimilar nature of their qualities.

Glazing appears to have been practised very early in oil-painting; and probably the use of varnishes over pictures painted with water-colours may have first shewn its utility. Indeed it could not fail to be the case, if the varnish employed happened to be tinged with any colour; for the lustre pictures acquired by that circumstance must be strikingly engaging: a harmony and sweetness are thereby gained, which all other means are vainly employed to obtain. It is therefore surprizing that all those who practised the art of painting after the discovery of the use of oil, should not have given in to the application of it. Yet it is certain that the Roman school is remarkably deficient in the knowledge of the value of this practice, and most frequently neglected to use it; owing probably to the employment painting found in fresco. The Venetian and Dutch schools, on the other hand, employed it in perfection, and it is in their works that a knowledge of it may best be acquired.

The principal difficulty attending the use of glazing, is to avoid the too common application of it; as it does not suit the representations of all substances, in its more immediate sense; though one general glaze over a picture, completed in its forms, will at all times benefit the work; if it happens not to be too low, or insipid, in its tones of colour.

All kinds of gems and polished substances, such as metals, silks, velvets, &c. are imperfectly wrought to effect, when it is not employed; and flesh, which is in nature compounded of a great variety of colours, is seldom quite perfect in its hue, when glazing is not employed to finish with. It is a species of it, produced by the yellow varnish being but partially removed from old pictures, which gives them their peculiar and brilliant lustre. It is quite impossible to make any effect exactly like it with fresh colours, unless some artifice be used to fore-run the effects of time; such as rubbing in dirt, and then partially removing it, &c. tricks which picture dealers are perfectly conversant with; and by which many an ingenious copy is passed off upon the unlearned amateur, to the enrichment of the dealer, and the future annoyance of the buyer, when time and improved information let him into the secret.

Glazing is the most valuable part of the practice of painting, when judiciously employed; as it produces clear broken tones of colour, which leave no remembrance of the palette, but deceive the eye by the variety of hues, and dazzling effect of light, produced by one colour shining through another in different degrees of illumination; much more like the effects of natural objects, than the use of opaque colours can possibly produce. But then great dexterity and judgment are required to use it properly in so general a manner. A well-informed and scientific artist knows the tone which one colour glazed over another will produce; and without that knowledge, a dirty dulness may be the effect, instead of the clearness required; and if not successful, it is always injurious; there is no medium in the application of it. If the under colour is not improved, it is sure to be deteriorated; and it will require repainting, to restore its original freshness. So that when a painter has prepared a work for glazing, (which should always be done with great clearness and precision,) the most extreme caution is requisite in adapting the tone of the glaze

which he proposes to use to the general hue of the picture before he applies it. It is not possible to give rules more explicit on this matter; the indefinite subdivisions of hues which all colours are capable of, must for ever leave to the feeling and judgment of the artist their peculiar application. It is hardly necessary to state that a glaze of red, over blue, will produce purple; of blue, over yellow, green; and of red, over yellow, orange; but it may aid the student in his practice, if he considers, that all the varieties of tone the original colours are capable of, will, when equally employed, produce a corresponding compound; and, of course, if his picture be of too red a hue, though of a light tone, a corresponding one of blue, or of yellow, will change it to the one he may require; and if he use the blue and yellow together as a green, it will produce a negative colour; totally destroying the red: but the varieties are too complicated and numerous to follow.

GLAZING of Cloth. The process of glazing is used for all the stout fabrics of cotton goods, and sometimes for those of linen. It is a part of the general processes of finishing goods for the market, and which is carried on by those who are generally called cloth-lappers, or calendermen. The glazing is done by putting on the cloth a small quantity of white wax, such as that used in the manufacture of wax candles, and the gloss is afterwards effected by the friction of any smooth body on the surface of the cloth. By the ordinary process the apparatus is very simple, consisting merely of a smooth table, a little inclined towards the operator, like a common writing desk, upon which the cloth to be glazed is spread smoothly, and drawn over, as occasion requires, from one end of the piece to the other. Above this is a lever, suspended from any convenient fixture to the roof, the lower end hanging in contact with the cloth, and by moving this backward and forward, the necessary friction is produced. The end of the lever next to, and in contact with the cloth, is faced with a smooth piece of flint or pebble, finely polished, and of a cylindrical form, the under surface of which is in contact with the cloth. This lever being drawn backward and forward by the operator's hands, the whole cloth is polished or glazed in succession, the joint at the top of the lever being fitted into a horizontal slider, which allows the polisher or flint to be moved from one side of the cloth to the other. In this way of glazing, the whole is performed by the power of a man's arms and hands; and, from the position of his body being constantly inclined over the table, is found to be a very laborious and fatiguing operation. The great number of people necessarily employed by this operation, and the difficulty of getting large quantities of goods rapidly glazed to answer the demands of hurried shipments for exportation, suggested lately the idea of a more speedy and efficacious manner of performing the operation of glazing by an improvement and alteration in the construction of the common five-bowl calender. This improvement was planned and executed at the extensive works of the late Mr. John Miller of Glasgow, who furnished the inventor with the means of carrying his plan into effect, and upon a proof of its efficacy on trial, his majesty's royal letters patent for its exclusive use to the inventor or his assignees within Scotland were obtained in the usual form. Two or three machines were then constructed for his own works, to which, as far as we know, they are still confined; and these machines have given the most universal satisfaction to all who have had their goods glazed by them, while at the same time an immense reduction of labour has been effected by their use.

The patent glazing machine, like the common calender, consists of five bowls, or cylinders, four of which are of

cast iron, smoothly turned, and finely polished on the surface, and the large or intermediate cylinder is generally of paste-board on an iron axis. In the common operation of smoothing by means of the calender, the velocity of the cylinders revolving upon their own axes, is in the ratio of their respective diameters, so that an equal quantity of superficies is constantly exposed of each. In the glazing-calender, or machine, it is only necessary that the motions of one of the cylinders should be so much accelerated as to produce the friction necessary to effect the glazing by rubbing against the other cylinders with which it is in contact, so as not to be liable to tear or otherwise injure the fabric. This motion is produced by means of wheels placed in the following manner: On the axis of the main cylinder A, is a cast iron wheel of any convenient diameter and number of teeth. This wheel works into the stud-wheel B, the number of whose teeth is not material to the speed, and whose diameter may be regulated so as to pitch well into the remaining wheels. The wheel is placed to revolve loosely on an iron stud, screwed into the frame-work of the machine. The stud-wheel B gives motion to the second stud-wheel C, and it continues the motion to the wheel D, which is fastened on the axis of the first iron cylinder. The upper cylinder works merely by friction, as in a common calender, and when the intermediate stud-wheel B is removed by being taken off the stud, the whole cylinders will revolve exactly as in the common machines, without producing any glazing effect. The simplicity of this machine, the regularity of the gloss which it gives, and the immense saving of labour, are powerful recommendations in its favour. The great quantity also which may be effected by it in a very limited time, renders it peculiarly adapted to meet the occasional exigencies of the exporter; and the additional advantage of its facility of adaptation to the purposes of the common calender, when glazing is not required, adds to its value and utility. Upon pressing occasions, one of these engines, by being constantly employed night and day, will glaze from 600 to 800 pieces of cloth, of 28 yards each, weekly.

Those employed in the late Mr. Miller's works are driven by means of a steam engine, by which also various other kinds

of machinery, adapted to the various operations of the business, are set in motion. Should any machinery of this description be constructed in works where there may be a general necessity of keeping them constantly employed for the purpose of glazing, it will be very necessary that care should be taken that the moving power, whether water, steam, or horses, should be ample; as it must be evident, even to those who are not practically conversant with the calculation of power and resistance, that this calender, when employed to glaze, must require considerably greater force to keep it in motion, than when the cylinders revolve in the ratios of their diameters, for the mere purpose of common calendaring or smoothing.

We are not in possession of sufficient data to enable us to ascertain, with any tolerable precision, the quantum of resistance added by the friction; nor are we aware that any accurate experiments have been made for that purpose: but it is evident that it must be very great in all cases. It is reasonable also to infer, that it may be considerably increased or diminished by the texture or fabric of the stuff upon which the glazing operation is performed. Hence, if these machines be employed constantly in large works, and set in motion by the same power, which also drives machinery adapted to other purposes, care must be taken that the power be sufficient to effect all the various purposes to which it is applied. And should this be attempted, under the impression that the glazing might be performed by the same power as common calendaring, a deficiency would be found, which must render it necessary to disengage part of the machinery, in order to give sufficient momentum to the rest. This is, perhaps, one of the most common, and at the same time, most ruinous errors into which the projectors of large works, who are not mechanics, are apt to fall. In the first instance, desirous that a large establishment should be set to work at the least possible expence, they too frequently calculate too barely, and are then obliged either to abandon their whole scheme at a great loss, to work it under serious and ruinous inconveniences, or to repair, at a triple expence, what they have left deficient at first.

Glue

GLUE, GLUTEN, a viscid, tenacious matter, serving as a cement to bind or connect divers things together.

There are divers kinds of glues made use of in the divers arts; as the common glue, glove glue, parchment glue: but the two last are more properly called *size*.

The common or strong glue is a commodity used by numerous kinds of artificers; as joiners, cabinet-makers, case-makers, hatters, book-binders, &c. and the consumption thereof is very considerable. The best is that made in England, in square pieces of a ruddy brown colour: Flanders glue, which is whitish and transparent, is held the next after the English. The most ordinary glue of France is black and opaque.

Glue is made of the skins of all kinds of beasts; as oxen, cows, calves, sheep, &c. The older the beast is, the better is the glue that is made of its hide. Indeed, it is rare they use whole skins for this purpose; those being capable of being applied to better purpose: but they make use of the shavings, parings, or scraps of the hides, and also horns; and sometimes they make it of the feet, sinews, nerves, &c. of beasts; and also of the pelts obtained from furriers.

That made of whole skins is the best, and that of sinews, &c. the worst: and hence, chiefly, arises the difference of glues, and the advantage of English and Flemish glues.

GLUE, method of making.—Mr. Clennell, in the Monthly Magazine for 1802, gives the following statement of the general mode of its manufacture. The materials above enumerated are “first digested in lime-water, to cleanse them from grease or dirt; they are then steeped in clean water with frequent stirring, and afterwards laid in a heap and the water pressed out. They are then boiled in a large brass cauldron with clean water, scumming off the dirt as it rises, and it is further cleansed by putting in, after the whole is dissolved, a little melted alum or lime finely powdered. The scumming is continued for some time, after which the mass is strained through baskets, and suffered to settle, that the remaining impurities may subside. It is then poured gradually into the kettle again, and further evaporated by boiling and scumming, till it becomes of a clear dark brownish colour. When it is thought to be strong enough, it is poured into frames or moulds about six feet long, one broad, and two deep, where it gradually hardens as it cools, and is cut out when cold by a spade into square cakes. Each of these is placed in a sort of wooden box open in three divisions to the back; in this the glue, while yet soft, is cut into three slices, by an instrument like a bow, with a brass wire for its string. The slices are then taken out into the open air, and dried on a kind of coarse net-work, fastened in moveable sheds four feet square, which are placed in rows in the glue maker’s field. When perfectly dry and hard it is fit for sale. That is thought to be the best glue which swells considerably without melting by three or four days’ immersion in cold water, and recovers its former dimensions and properties by drying. Glue that has got frost, or that looks thick and black, should be melted over again. To know good from bad glue, the purchaser should hold it between his eye and the light, and if it appears of a strong dark colour, and free from cloudy and black spots, the article is good.” When glue is used by the carpenters, they break it and soak it for about 24 hours in cold water; and then melt the soaked

pieces, causing it to simmer for a quarter of an hour over a slow fire and frequently stirring it. When cooled it becomes a firm gelly, which may be cut by any instrument. It is merely warmed for use, and in this state spread over the surface of the wood with a stiff brush. In an interval from one to three days the pieces of wood will be so perfectly cemented, that boards, thus cohering, will as readily break in any part as separate at the junction. Glued boards will not set in a freezing temperature; the stiffening being occasioned by the evaporation of the superfluous matter of the glue, which is prevented by a considerable degree of cold.

GLUE, Bees. See **WAX**.

GLUE, Fish, is a sort of glue made of the nervous and mucilaginous parts of a large fish, found chiefly in the Russian seas.

These parts, being boiled, bear a near resemblance to that viscid matter found on the skins of cod-fish. When boiled to the consistence of a jelly, they spread it on a leaf of paper, and form it into cakes; in which state it is sent to us.

Fish-glue is of considerable use in medicine, and divers others arts; where it is better known under the name of isinglass and ichthyocolla. See **ISINGLASS**.

A strong and fine glue may be prepared with isinglass and spirit of wine thus: steep the isinglass for twenty-four hours in spirit of wine or common brandy. When the menstruum has opened and mollified the isinglass, they must be gently boiled together, and kept stirring till they appear well mixed, and till a drop thereof, suffered to cool, presently turns to a strong jelly. Then strain it, while hot, through a clean linen cloth, into a vessel to be kept close stoppered. A gentle heat suffices to dissolve this glue into a transparent and almost colourless fluid, but very strong; so that pieces of wood, glued together with it, will separate elsewhere than in the parts joined. Boyle’s Works abridg. vol. i. p. 130.

A strong compound glue may be made by infusing a mixture of common glue, in small pieces, with isinglass glue, in as much spirit of wine as will cover them, for about twenty-four hours: then melt the whole together, and add as much powdered chalk as will make it an opaque white.

A strong glue, that will resist moisture, may be obtained by dissolving gum sandarac and mastic, of each two ounces, in a pint of spirit of wine, and adding about an ounce of clear turpentine: then take equal parts of isinglass and parchment glue, and having pounded them into small pieces, pour the solution of the gums upon them, and melt the mixture in a covered vessel, with a heat less than that of boiling water: then strain the glue through a coarse linen cloth, and putting it again over the fire, add about an ounce of powdered glass.

Or, a strong glue, that will resist water, may be made by adding half a pound of common isinglass glue to two quarts of skimmed milk, and evaporating the mixture to a due consistence.

A glue, that will hold against fire and water, may be made by mixing a handful of quick-lime with four ounces of linseed oil, boiling them to a good thickness, and spreading the mixture on tin plates in the shade: it will thus become exceeding hard, but will easily be dissolved over a fire, and be fit for use. See **CLEMENT**.

Gold

GOLD. *Gold*, Germ.; *Guld*, Swed. Dan.; *Or*, Fr.; *Arany*, Hung.; *Soloto*, Russ.

Mineralogical Description.—This metal never having been found in a mineralized state, we are acquainted with one species only, namely,

Native gold, which is subdivided by Werner into three sub-species, viz. *gold-yellow*, *brass-yellow*, and *greyish-yellow gold*. Though this subdivision may appear arbitrary, and not founded on constant characters exclusively belonging to each of the above varieties or sub-species, it is nevertheless entitled to attention, since colour, however unimportant it may be in the classification of earthy fossils, constitutes a character of considerable value in native metallic substances, the range of whose colours is confined to a narrow compass. But also their geognostic relation appears to constitute a distinction, at least between the two first of the Wernerian sub-species; for as to the third, or the *greyish-yellow gold*, its claims to be kept separate from the two others appear doubtful: all we know of it is its being found in small flat particles, along with that mixture of different metals called pla-

tina in grains, of whose colour it partakes in general, and with which it is supposed to have occurred also originally under the same geognostic relations.

1. *Light or Brass-coloured native Gold.* Messing-gelbes gediegen gold of Werner. Its colour is pretty well indicated by its name; but it varies in intensity from what may be called pale-gold yellow to yellowish-silver white. It is also sometimes found with deep-yellow, and with pavonine tarnish.

It occurs massive, disseminated in angular and amorphous particles, but more frequently in films, membranes, and plates even and curled or-twisted, and with smooth or drused surface; also capillary, tooth and wire-shaped, shrub and fern-like, and as moniliform strings; often imitating reticulated and filigree work; all which forms are generally produced by the aggregation of minute imperfect crystals. Among these, perfect crystals are not unfrequently seen, sometimes single, oftener in groups, on the margin of the plates, &c. The following secondary forms have been observed: the cube; the octahedron; the garnet-dodecahedron; the leucite-dodecahedron with trapezoidal planes. Also modifications intermediate between the cube and the octahedron occur, but they

are scarce. The minute three-sided pyramids, which are often seen to druse the membrane, and the simple triangular marks on the plates of the Transylvanian native gold, are the results of hurried and disturbed crystallization; the former of them being the solid angles of the cubical, and the latter the rudiments of the octahedral variety.

The crystals are minute (those described by Mr. Esmark as octohedra and cubes of two lines in diameter, have never before been heard of); their surface is always smooth.

Lustre metallic: externally splendid: while that of the grains is sometimes glistening, sometimes approaching to dull; internally it is glimmering and glistening.

The fracture of gold is fine hackly. Its fragments are indeterminately angular.

It is soft, highly flexible, malleable, and ductile.

The specific gravity of pure gold is from 19.253 to 19.640; but that of the brassy-yellow variety, owing to a greater proportion of silver with which it is alloyed, is generally considerably less, though always above twelve.

The light, or brassy-yellow gold, occurs almost always in veins in greywacke, greywacke slate, and newer porphyry; seldom, as the following sub-species, in primitive rocks, or under other circumstances that bespeak a similar remote antiquity.

It occurs chiefly with quartz and iron pyrites, and not unfrequently with grey antimony. Other concomitant substances are, among the earthy fossils, calcareous spar, brown spar, barytes, selenite, and seldom small quantities of bole, lithomarge, and common garnet; of metallic substances, red and vitreous silver ores, (seldom native silver,) copper pyrites, grey copper ore, copper green, brown iron stone, galena, green lead ore, blende, with occasional traces of white cobalt, copper nickel, red orpiment, native arsenic, and arsenical pyrites.

2. *Deep or Gold-yellow Native Gold.*—Gold-gelbes ge-diegen-gold of Werner.

Its colour is the highest gold-colour, seldom verging on brassy yellow.

It occurs massive and in small roundish and flattened pieces, as also in grains of various dimensions, detached or disseminated; seldom in particular external forms, such as in leaves and laminæ, filiform and mosslike; scarcely ever crystallized: almost all the crystalline forms described by authors belonging to the light-coloured sub-species.

External lustre glistening, sometimes (as in the variety called Spanish snuff) divested of all lustre. Its specific gravity is rather greater than that of the light or brassy-coloured gold, with which it agrees in the remaining characters.

It occurs mostly loose, in alluvial situations, and in the sand of rivers, and, as such, appears to have been originally disseminated in rocks of ancient formation: it is, however, also found in veins in Norway, Siberia, Bohemia, Hungary, in the East Indies, &c. almost always disseminated in quartz, accompanied by iron-pyrites; but nothing is as yet known respecting the age of these veins. At Fatzebay it is found in minutely mosslike external forms, often of a dull powdery appearance, on common quartz sometimes mixed with iron pyrites; in this state it is by the miner called Spanish snuff.

Geographical situation.—The following localities comprehend both the sub-species into which native gold is divided by Werner. By far the greater part of that found in Europe belongs to the brassy-yellow sub-species, except the gold of rivers and alluvial soil, which is principally deep yellow, and to which the immense quantities of this precious metal, furnished by the other parts of the world, appear likewise to be referable.

Europe.—Hungary, the Bannat, and principally Transylvania. In Upper Hungary it occurs in gneiss: at Schemnitz, in Lower Hungary, it is found accompanied with several silver ores, and with galena; at Kremnitz, in and on cellular and shattered quartz, lamellar barytes, with vitreous silver and grey copper ore, copper pyrites, brown spar, &c.; at Oravizza, in the Bannat, it occurs filiform and disseminated in pale flesh-red and greenish-white limestone, with white cobalt ore and copper nickel. In Transylvania, the richest country of Europe in this metal, it principally occurs in a kind of clay-porphry of different degrees of freshness, which is the *Saxum metalliferum* of Born, in *grauwacke* and *grauwacke slate*: at Kapnik it is sometimes found with red orpiment: at Stauisfa in calcareous spar, mixed with arsenical pyrites, &c.: other places of Transylvania abounding in gold (which is for the greater part brassy-yellow), are Vereshpatak, Abrudbanya, Boiza, Offenbanya, Fatzebay, Toplitz, Treflityan, &c. Also the rivers, both of Hungary and Transylvania, are richly auriferous; gold sand is found in the Nera, and underneath a stratum of chalk on the plain traversed by this river. The richest river of Transylvania is the Aranyosh, and the plain bordering on the river Morosh, contains likewise gold in grains, between a stratum of mould, and another of schist, neither of which strata is in the least auriferous. Also at Olapian, gold is obtained by washing; it is there mixed with magnetic iron stone, titanium, garnet, and cyanite. The gold of the great rivers of Transylvania is generally of 21 carats, that of Olapian and Roshinar is even of 23 carats, six grains.

In Germany it is found in several places, at Johangeorgensstadt in Saxony, in Carinthia, where it accompanies copper-ores, in Tyrol and Salzburg; but it is only in the last of these districts, or rather in the chain of mountains, separating Tyrol from Carinthia, that gold-mines are worked: in the Zillerthal it is found in various external forms, and accompanied with iron-pyrites, &c. in mica slate. In Bohemia gold occurs in quartz.

Spain is probably very rich in gold; certain it is that considerable gold mines were worked there in former times, and, according to Diodorus Siculus, as far back as the time of the Phœnicians, after whom the Romans undertook to work them; and Pliny informs us, that those nations derived great profit from them. Asturia was the province which furnished most of this metal. After the discovery of America these mines were entirely given up and lost. The Tagus and some other rivers of Spain are likewise auriferous.

France has no gold mine that is worthy to be worked; the first discovery of gold in that country was made in 1781, at la Gardette, in the valley of Oisans, in the present department of the Isère: the mine was worked for six years, but the produce in gold and accompanying minerals was too small to compensate for the expence of obtaining them, and, indeed, the loss amounted to upwards of 21,000 livres. It occurs there, with rock crystals and iron pyrites, in gneiss. The sand of several rivers of France is auriferous, such as that of the Arrieze near Mirepoix, the Gardon and Cèze in the Cévennes, the Rhone in the Pays de Gex, the Rhine between Strasburg and Philipsburg, the Salat in the neighbourhood of St Giron, in the Pyrenees, the Garonne near Toulouse, and the Hérault at Montpellier. Also most of the black sand and of the bog-iron found in the neighbourhood of Paris is said to contain a small quantity of gold.

In Piedmont veins of auriferous pyrites and quartz are found near Macugnaga, at the foot of Monte Rosa: which mountain consists of veined granite in horizontal beds. The veins of pyrites and quartz have upon the whole a perpendicular direction, but in some parts they cross each other,

and where this takes place, *grubbi*, or nests, are found which contain the greatest proportion of gold. The proprietor of these mines extracted out of such nests, in no more than twenty-two days, 189 marcs of pure gold, although a hundred weight of the ore yields no more than from 10 to 12 grains of that metal. Formerly upwards of a thousand workmen were employed in these gold-mines; and the proprietors still possess 86 mills, by which from 10 to 12 pounds (of 12 ounces) of mercury impregnated with gold are produced per day. Twelve pounds of mercury contain two marcs of gold. There are likewise several auriferous rivers on the S. side of the Apennine Alps, between mount Rosa and the valley of Aosta, such as the Avanson, which runs from the valley of Challant into the Doire, and where some gold-mines were also worked by the Romans; the Orco, &c.

Sweden has a gold mine at Edelfors in Smoland: the gangue, a brownish quartz, is said to be in a kind of hornblende slate, which also contains the metal disseminated.

Gold has also been found in Great Britain: in Cornwall; at Lead-hills, in Scotland, disseminated in quartz; at Wicklow, in Ireland, under the soil, and in a stream which runs over rocks of clay-slate with veins of quartz. It belongs to the deep yellow variety.

Asia—The gold-ores of Siberia are partly of the light coloured, but principally of the deep coloured variety: that of Berezo, which occurs in pyrites, or rather brown iron stone, and iron shot quartz, and in the rock which serves as gangue to the red lead ore, belongs to the latter. Patrin mentions a specimen of gold in spangles on hornsilver, found in one of the silver mines of Schlackenbergl.

The geognostic relation of the gold found in several parts of India, in Japan, the Philippine and Maldivé islands, Sumatra, Borneo, &c. is not known; all the specimens from India, that have come under our inspection, were in the form of small rounded and amorphous particles in quartz, and belonged to the deep yellow variety.

Africa—Of the occurrence of gold in this part of the world we know so much, that the greatest part, at least of that which comes to Europe, is deep yellow and in grains. African travellers have made us acquainted with a few of its localities, but not with any particulars relating to its geognostic habitudes. Though the commerce of gold-powder extends almost over the whole of Africa, yet, according to Heeren, there is none to be found in its northern parts. Among the principal African gold mines are those of Kordofan, between Darfur and Abyssinia, mentioned by Browne. The ancients, says Brongniart, appear to have been acquainted with these mines: they considered Ethiopia as a country rich in gold; and we find in Herodotus, that the king of that country exhibited to the ambassadors of Cambyles all the prisoners of war fettered with chains of gold.

A second most considerable district for gathering gold-powder appears to be southward of the great desert of Zahara, in the west of Africa, at the foot of those lofty ridges of mountains on which originate, among many smaller rivers, the Senegal, the Gambier, and Niger. The country of Bambouk, at the N.E. of these mountains, is, according to Golberry, that which furnishes the greatest quantity of gold which is sold on the west coast of Africa, from the mouth of the Senegal to the Cape Palmas. This gold is found in spangles and small lumps, principally near the surface of the earth, in the beds of rivulets, and always in a ferruginous soil. In some parts of the country the negroes sink something like shafts, but without giving any support to the sides of the pit; nor are they wont to follow up the vein, if any should appear, or to make galleries. The metal is obtained by repeated washing of the earth that includes it. The same country furnishes likewise

the greatest part of the gold carried to Morocco, Fez, and Algiers, by the caravans which, from Tombuctoo, travel through the great desert of Zahara. The gold which is brought to Cairo and Alexandria from Senaar comes likewise from these. See Parke's travels, where also an interesting account is to be found of the gold in Manding, and of the process by which the negroes obtain it.

The third principal district of Africa, for collecting gold, is on the S.W. coast between 15° and 22° S. lat. opposite Madagascar. This gold comes principally from the country of Sofala. According to the relation of some travellers in this part of the world, the gold is found there not only in powder, but likewise in veins. Some are of opinion that the country of Ophir, from whence Solomon obtained gold, was situated on this coast.

America.—The gold of this part of the world, as far as we are acquainted with it, is so equally the production of the sand of rivers and of alluvial land; but it is also, though rarely, found in veins. South America, particularly Brasil, Choco, and Chili, are the countries that yield most; but some is also found in North America, particularly in Mexico, where it occurs along with silver-ores. The annual produce of these Mexican mines is valued at from 12 to 1500 kilograms. All the rivers of the Caraccas, 10° north lat. are auriferous.

The gold of Chili, according to Frezier, is lodged in the alluvial formation.

The Peruvian gold occurs in ferruginous quartz; that of Choco, the richest province in gold in South America, is found as grains in alluvial country, and in rocks belonging to the newest fletz-trap formation. Almost all we know respecting the geognostic situation of the gold of Spanish America, we owe to M. de Humboldt.

Brasil furnishes gold in abundance, and it is from thence that the greatest part actually seen in commerce is brought to Europe. There are, however, properly speaking, no gold-mines in that country; the gold is not found there in veins, but disseminated in sand and other alluvial depositions, out of which it is obtained in the usual manner.

The gold that has been furnished by Brasil within 120 years, may be valued (according to Correa) at 2,400,000,000 of French livres; and, according to other authors, the amount is calculated to be 24,000,000 per annum. Brongniart. See ORES.

Observations.—1. It would appear that most writers who adopt Werner's distinction between gold-yellow and brass-yellow gold, have mistakenly described the one sub-species for the other, and some even speak of "grey-yellow gold" from Transylvania." The sub-division alluded to may be deemed inadmissible; but if it be at all adopted, by far the greater part of the native gold of Transylvania and Hungary, and consequently almost all crystallized gold, must necessarily be referred to the light-coloured, and that found in the sand of rivers to the deep-coloured sub-species; and this not on account of their colour only, usually indicative of differences in the chemical composition of metals, but principally on account of the geognostic relations under which they respectively occur, and on which great stress appears to be laid by Werner.

2. Iron pyrites, containing not unfrequently a considerable portion of gold, in most cases invisibly dispersed and disguised, has by some been considered as a species of gold ore; a distinction to which (though such auriferous pyrites are often subjected to metallurgical treatment for extracting that metal, as will be seen hereafter) it cannot be considered as entitled. See PYRITES, *Auriferous*.

The brown cubic crystals from Beresof, in Siberia, which contain grains of gold, are considered by some as decomposed, by others as hepatic pyrites, and by some as brown iron stone in supposititious crystals. Whatever they may be, they are certainly not what Werner means by hepatic pyrites.

3. The native gold of Transylvania is often accompanied, and sometimes incruited, by particles of a pale yellow earthy substance, which was considered by Hacquet as an oxyd of gold. Muller and others have described it as iron-ochre, from which, however, it appears to differ both in colour and consistence. It is almost always to be met with in the specimens of native gold from Vereshpatak, but sometimes in such fine particles as to appear merely as a tarnish on the metal. It is to this dust probably that the gold ore, called Spanish snuff, owes its mat, yellowish-brown colour. It deserves further examination.

4. The grey metallic substance occurring as acicular indeterminate crystals, along with the gold of Siberia, in quartz, and which has been described as tellurium, as grey copper ore, &c. appears to be native bismuth.

For the *chemical characters* of gold, and the *uses* to which it is applied, see the sequel of this article.

Extraction of Gold—This metal is obtained separate from foreign substances, with which it is mixed by amalgamation with quicksilver. After it has been freed, by pounding and washing, from the stony matter, it is triturated with about ten times its weight of mercury. The more fluid part of the amalgam is forced through leather, while that which is more consistent, and which contains the chief part of the gold, remains. This is subjected to distillation, the quicksilver is separated and evaporated, and the gold remains in a state of fusion. When this metal is found in other ores, they are first roasted, to disperse the volatile principles, and to oxidize the other metals. The gold, which is but little subject to oxydation, is extracted by amalgamation, by cupellation, or other methods adapted to each ore, according to its properties or constituent parts. The metal obtained in these ways is always more or less alloyed, particularly with silver and copper. The first step in its purification is the process of *Cupellation*, to which article in our Cyclopædia the reader is referred for accurate information on this part of the subject.

The gold, after it has been submitted to this process, is often alloyed with silver, which, being nearly as difficult of oxydation, is not removed by the action of lead, and hence the necessity of the operations denominated *Parting* and *Quartation*, which may be explained in a few words.

In *Parting*, the metal is rolled out very thin, and cut into small pieces, which are digested in diluted nitric acid moderately hot. The acid has an action upon, and dissolves the silver, leaving the gold undissolved in a porous mass. When, however, the proportion of silver is very small in comparison of the gold, the latter sometimes protects the former from the action of the acid; in such cases the previous step of *Quartation* is employed, which is so named on account of the proportion of materials employed, *viz.* three parts of silver, with one of gold, and then subjecting the alloy, rolled out, to the operation of the acid. Sometimes they are melted together, and sulphur thrown in, the sulphur combines with the silver, and the gold falls to the bottom. It is observed by Lagrange, that rolling and annealing are operations very necessary to the success of the parting process, and which require some precautions. If the plate must not be too thin, lest it should break in consequence of the motion communicated to it by the action of the acid; if it is too thick the acid could not penetrate to its centre.

2dly. The annealing of the plate, at the same time that it gives pliability, facilitates its being rolled without cracking; it also opens the pores of the metal, which the rolling may have pressed together, and by these means favours the action of the acid.

The process recommended by Bergman is this: first to dissolve it in nitro-muriatic acid; the silver is deposited spontaneously in the form of muriate of silver, which is insoluble; the gold is precipitated in fine powder by the sulphate of iron. Each of the above-mentioned processes is performed in such a manner as to lead to an estimate of the quantity of gold, and also of the different metals with which it is alloyed.

Gold, it is said, by some able French chemists, as Le Sage and Rouelle, exists in the vegetable kingdom, it having, in experiments instituted for the purpose, been extracted from the ashes of certain plants; the quantity, however, being, of course, too trifling to be sought after for practical purposes, it is sufficient merely to mention the fact in this place.

GOLD, Chemical Properties of.—Gold melts at the temperature of 32° of the scale of Wedgwood; and what is very remarkable is, that it is more difficult of fusion in the state of filings and grains, than in larger masses; and that the small fragments, even after they are fused, remain in separate globules: and in order to make them run into one mass, a little nitre or borax is thrown into the crucible. Gold, which has only been subjected to a degree of heat barely necessary for its fusion, is brittle after cooling. To preserve its ductility, which, as will be seen farther on, is one of the more important mechanical properties of gold, the temperature must be raised much higher. It is brittle also when it is too suddenly cooled after fusion. By an increase of temperature while the gold is in fusion, it becomes convex on the surface, and when it cools, it sinks, circumstances which are ascribed to the expansion and contraction of the metal. When it is gradually and slowly cooled, it crystallizes in the form of quadrangular pyramids, or regular octahedrons. If the heat be continued while it is in perfect fusion, it seems to undergo a kind of ebullition. This circumstance was noticed by Homberg and Macquer, as well in the application of the burning-glass, as when a small globule of the metal was acted on by the blow-pipe. Macquer asserts that it rose in vapour to the height of five or six inches, and attached itself to the surface of a silver plate, which it completely gilded.

The strongest heat of a furnace, which has been applied to gold in fusion, has been found incapable of producing the smallest change or the least tendency to oxydation; but, by the action of a very powerful burning-glass invented by Tschirnhausen, and which has been described under the article BURNING-GLASS, Homberg found that gold, placed in its focus, not only rose in vapour, but that it was covered with a violet-coloured vitreous oxyd. The experiment was frequently repeated, so as to ascertain the fact most completely. The same thing has been done by means of the electric discharge, by which gold-leaf, placed between two cards, has been converted into a violet-coloured powder. These instances of real oxydation were, at first, regarded, by some who witnessed the experiments, as merely minute mechanical divisions of the metal, but this apparent objection has been removed by the experiments of Van Marum on the combustibility of gold by means of the large electrical machine at Haerlem. A strong electrical shock was passed through a golden wire suspended in the air. It kindled, burned with a perceptible green flame, and was reduced to fine powder, which was dissipated in the air. A similar oxydation had been observed to take place on the gilding in the inside of

houses, or on the furniture which has been struck with lightnings. The purple oxyd of gold, thus obtained, contains five or six *per cent.* of oxygen. By precipitation from some of its saline combinations, a yellow oxyd has been obtained, in which the proportion of oxygen amounts to ten *per cent.* The oxyd in both instances may be decomposed, and the oxygen completely expelled, by an elevation of temperature not much superior to that of ignition.

The attraction of gold to oxygen is so weak, that it is scarcely affected by the greater number of acids. It was formerly supposed to be perfectly insoluble in the nitrous and nitric acids, which in general part with oxygen with so much facility, and when gold leaf is put into the acid cold, it seems to suffer no change, but when nitric or nitrous acid is boiled on gold, it is capable of dissolving a small portion of it. The quantity dissolved is, however, so inconsiderable, and depends on so many conditions, which it is needless to enumerate, that the accuracy of the processes of assaying can scarcely be affected by it.

When gold is dissolved in the nitro-muriatic acid, or in a mixture of equal parts of nitric and muriatic acids, an effervescence takes place, and the solution becomes of a yellow colour. In this process the nitric acid is decomposed, its oxygen combines with the gold, and the oxyd, as it is formed, is dissolved in the muriatic acid. By adding lime-water a precipitate is formed, which is the yellow oxyd of gold; consisting of from eight to ten parts of oxygen in the hundred. There is no action between gold and azote, hydrogen, carbon, or sulphur: but the oxyds of gold are readily decomposed by hydrogen, as will be soon seen.

Phosphorus combines with gold by heating together in a crucible a mixture of one part of gold in filings, with two parts of phosphoric glass, and an eighth part of charcoal. Great part of the phosphorus is separated from the acid, and driven off, but there remains a small quantity united with the gold, forming a phosphuret of gold. It may be done also by adding phosphorus to gold in a red heat in a crucible. It is, in this state, pale coloured, granulated, brittle, and a little more fusible. The proportion of phosphorus is not more than one part in twenty-four; and the substance may be decomposed by being kept in fusion; the phosphorus is driven off in the state of vapour, and inflamed. Bergman has arranged the affinities of gold and its oxyds in the following order:

<i>Gold.</i>	<i>Oxyds of Gold.</i>
Mercury,	Muriatic-acid,
Copper,	Nitric,
Silver,	Sulphuric,
Lead,	Arsenic,
Bismuth,	Fluoric,
Tin,	Tartaric,
Antimony,	Phosphoric,
Iron,	Prussic.
Platina,	
Zinc,	
Nickel,	
Arsenic,	
Cobalt,	
Manganese.	

Salts of Gold.—These are the nitrate and muriate.

1. *Nitrate of Gold.* When concentrated nitric acid is several times successively poured upon gold, boiled and distilled to dryness, the gold is dissolved, and the solution assumes a yellowish colour. This solution is more readily effected in proportion to the quantity of gas or nitrous gas which the acid contains. Gold-leaf, according to Fourcroy, is dissolved in

nitric acid, impregnated with nitrous oxyd, and he supposes that it is owing to the nitrous oxyd that the gold is oxydated, this oxyd being so much more easily decomposed than the nitric acid. The acid which, at first, is deprived of its colour by the oxydation of the gold, as this oxyd is dissolved, assumes an orange-yellow colour, holding in solution the nitrate of gold with an excess of acid. The nitrate cannot be obtained in crystals, and it is decomposed by heat or by being exposed to the light of the sun; it is also decomposed by the alkalies, or by introducing a plate of tin or silver into the solution, and the purple oxyd is precipitated in the form of powder; and likewise by muriatic acid, which at the instant of combination converts the orange-colour to a pure yellow.

2. *Muriate of Gold*—Muriatic acid of itself has no action on gold, or on its purple oxyd, but gold is immediately oxydated and then dissolved in oxymuriatic acid: or if nitric acid be added to the muriatic in certain proportions, the solution of gold in the mixture is readily effected: hence the nitro-muriatic acid was distinguished by the name of “*aqua regia*,” because it dissolved gold, which was regarded by the alchemists as the king of metals. The nature of the chemical action is thus explained. Gold is oxydated with great difficulty, but it is effected by oxymuriatic acid, which readily parts with its oxygen, or by the addition of the nitrous to the muriatic, the former of which is decomposed, giving out its oxygen to the gold, which being now oxydated is dissolved in the muriatic acid, forming with it a muriate of gold. This solution of the muriate of gold is of a deep yellow colour, extremely acid and caustic; has an astringent metallic taste, and stains the skin of a deep purple colour, which becomes darker by exposure to the air and light. It produces a similar effect on all vegetable and animal matters, and on marble and siliceous stones. By evaporating the solution to one half, nitric acid is disengaged, and crystals are obtained. These assume a red colour by the action of strong light. They attract moisture from the air, and spontaneously become liquid. When oxymuriatic acid is used, the oxygen of this acid being retained even by a weaker affinity than the nitric acid, the gold attracts it, and combines with the muriatic acid. In this case the solution is slow, and but a very small quantity of gold can be dissolved, partly from the oxymuriatic acid not being in a very concentrated state, and partly, it is supposed, from the quantity of oxygen present not being such as to form a sufficient quantity of oxyd to saturate the acid. It ought, however, to be observed, that if the late discoveries of professor Davy be established, which make the oxy-muriatic acid a simple substance, and even possessing no oxygen whatever, then a new theory must be introduced to account for the facts above-stated. In oxy-muriatic gas, gold-leaf is instantly fused with inflammation, and dissolved.

Gold cannot be dissolved by the other acids when in its metallic state, but its oxyds may be combined with them, and a number of the salts of gold be formed. The sulphate and nitrate also, as we have seen, do not crystallize: the phosphate of gold may be fused, and in this state it forms a fine red glass. We shall now briefly notice some of the properties of the muriate of gold. In connection with this subject, we must not omit the experiments of Mrs. Fulhame, which she announced in an “*Essay on Combustion*,” with a view to a new art of dyeing and painting, &c. in the year 1794, and which were, at that period, expected to lead to some important practical results.

The muriate of gold is very soluble in water, and is decomposed in hydrogen gas. If a piece of silk be moistened

with a solution of muriate of gold, the salt is decomposed, and the gold, reduced to the metallic state, attaches itself to the silk. It is decomposed also by phosphorus. If a stick of phosphorus be introduced into a saturated solution of muriate of gold, the salt is decomposed, and the gold, being reduced to the metallic state, forms a cylindrical covering to the phosphorus, which may be separated by dissolving the latter in hot water. A similar effect is produced by burning sulphur, by sulphurated and phosphorated hydrogen gases, and by sulphurous acid. If a solution of muriate of gold be cautiously added to sulphurous acid, a fine pellicle of gold appears on the surface, which is instantly precipitated in the form of small grains. These, and many other experiments equally curious and interesting, were first described by the lady above-mentioned, and the rationale of the subject is thus explained. All the substances which have been enumerated have a stronger affinity for oxygen than gold, so that the oxyd of gold, in combination with the acid, is decomposed; the oxygen combining with the hydrogen, and forming water, or with the phosphorus or sulphur, and forming sulphuric or phosphoric acid.

The muriate of gold is soluble in ether, and forms with it a solution of a golden yellow colour, which floats on the top of the fluid. By the addition of ether to a solution of gold, and agitating the mixture, as soon as it is left at rest, the two liquids separate, the ether rises to the top, and assumes a yellow colour, while the nitro-muriatic acid remains below and becomes white. By a process of this kind a tincture of gold was prepared, called "potable gold." The solution of gold in ether is not permanent: it is quickly reduced to the metallic state, and is sometimes found crystallized on the surface. The ethereal solution is used by Mr. Stodart for defending lancets, and other surgical instruments, from injury by a moist atmosphere.

The muriate of gold is decomposed by all the alkalis and earths, and is reduced to the state of yellow oxyd.

Most of the metals decompose the muriate of gold: copper, iron, zinc throw down the gold in its metallic state: other metals, as silver or lead, in the state of purple oxyd. The precipitate obtained by means of tin is valued for the beauty of the colour which it gives to glass or enamel. This preparation is known to artists by the name of the "Purple powder of Cassius," and it may be obtained by various processes. That which is commonly resorted to, is to dissolve pure gold in a nitro-muriatic acid, which is composed of three parts of nitric and one of muriatic acid. A solution of tin is to be prepared by dissolving the metal, in small portions at a time, in an acid containing two parts of nitric and one of muriatic acid, previously diluted with an equal weight of water. This solution, after it is saturated, is largely diluted, perhaps with a hundred parts of distilled water; to this the solution of gold equal in quantity to half the quantity of solution of tin, is added, and the precipitate is obtained after it is allowed to subside, which is to be washed and dried. This is the only known preparation capable of giving a red colour to glass; and if the experiment be performed with accuracy and judgment, the glass so treated serves as a capital imitation of the ruby. The process is, however, attended with considerable difficulty, owing to the colour of the precipitate being various, from circumstances not easily discovered. According to Pelletier, it is a compound of oxyds of tin and gold; and its formation is owing to the strong attraction of the tin for the oxygen, with which it is disposed to combine in large quantities. When the solutions, above described, are mixed, the oxyd of tin, which is nearly at the minimum of oxydization, at-

tracts part of the oxygen of the oxyd of gold: the two oxyds thus brought to states of oxydization, different from those in which they existed in the separate solutions, and probably likewise exerting mutual affinities, are no longer soluble, and are precipitated in combination. Muriate of gold is decomposed by some other metallic salts, in consequence of similar actions; the oxygen of the oxyd of gold being attracted by the oxyd of the other metal, which hence passes to a higher state of oxydization. Those which have a strong tendency to exist in such a state, are capable even of completely de-oxydizing the oxyd of gold. Example.—If a solution of the green sulphate of iron be added to the solution of muriate of gold, the gold is precipitated in very minute particles in the metallic state, while the iron passes to the state of a red sulphate. A solution of muriate of gold, when concentrated by evaporation, yields beautiful yellow crystals, not unlike topazes.

Gold, as we have seen, does not combine with sulphur by fusion, and on this is founded a method of freeing it from silver or other metals, the alloy being fused with sulphur, the silver, &c. unite with the sulphur, leaving the gold separate. But gold and sulphur may be united by the medium of an alkali. Example.—Let a sulphuret of potash be fused with one-eighth of its weight of gold-leaf, and the combination is even soluble in water, the solution being of a green colour.

Alloys of Gold.—Gold forms alloys with the greater number of the metals, which produce on the metal so alloyed a very particular change in its properties. An extensive and accurate series of experiments on these alloys was made by Mr. Hatchet, with the view of determining some important and interesting facts relating to the use of gold as a coin. Of these we shall give a brief abstract, referring our readers for a more particular account to the Transactions of the Royal Society for the year 1803.

The chief enquiry of Mr. Hatchet, as connected with the alloys of gold, was, whether soft and ductile gold, or gold made as hard as is compatible with the process of coining, suffers most by wear. His experiments were intended to examine the effects which various metals produce upon gold, when combined with it in given proportions, beginning with $\frac{1}{12}$ th, which is the standard proportion of alloy, and gradually decreasing to $\frac{1}{100}$ th part of mass. The results drawn from the trials were, that fine gold, alloyed with silver, with copper, and with tin, did not suffer any loss during the experiment. The gold alloyed with lead only lost three grains, chiefly by vitrification; with iron it lost 12 grains, which formed scoria; with bismuth it lost 12 grains, chiefly by vitrification; with zinc it lost a pennyweight by volatilization; and with arsenic, it not only lost the whole quantity of alloy, but also two grains of the gold which were carried off in consequence of the rapid volatilization of the arsenic. Hence it was inferred that only two metals are proper for the alloy of gold coin, namely, silver and copper; as all the others either considerably alter the colour, or diminish the ductility of gold. In respect to the latter quality, the different alloys employed in this series of experiments appear to affect gold nearly in the following decreasing order: 1. Bismuth. 2. Lead. 3. Antimony. 4. Arsenic. 5. Zinc. 6. Cobalt. 7. Manganese. 8. Nickel. 9. Tin. 10. Iron. 11. Platina. 12. Copper, and, 13. Silver. The three first have nearly the same effect on gold, and bismuth is found to render gold brittle when the proportion of that metal is to gold only as 1 to 1920; even the vapour arising from bismuth, lead, and antimony in fusion, produces these changes.

The alloy with platina is of a yellowish white colour, very ductile, and of a considerable specific gravity. The alloy with silver in the standard proportion, or 1 to 12, approaches, as we have seen above, the nearest to the ductility of fine gold of any alloy, and its specific gravity differs but little from the mean specific gravity of the two metals. When the silver amounts to $\frac{1}{4}$ th, the colour of the alloy approaches to green, and forms the green gold of the goldsmiths. In combination with copper, gold has its colour rather heightened than impaired; its hardness is increased and its ductility very little lessened, when the standard proportion of 1 part in 12 is not exceeded. This alloy of 22 carats fine is generally used, when gold is fabricated into plate or ornaments, and likewise forms the gold coin of the country. With quicksilver, gold unites with great facility, making with it an amalgam which will be described hereafter. The alloy with iron is much harder than gold, very ductile and malleable; but the colour is debased to a dullish grey, inclining to white. Tin was formerly regarded as the metal which rendered the alloy with gold the most brittle of all the alloys, but the experiments of Mr. Bingley and Mr. Hatchett have shewn that this notion is to a certain extent erroneous, and that the effects produced by the mixture of tin with gold, ought probably to be ascribed to other metals, with which the tin was contaminated, such as bismuth, antimony, lead, and zinc. The alloy, consisting of equal parts of zinc and gold, is very hard and susceptible of a fine polish, and not being subject to much alteration from the air, it is recommended for the fabrication of the mirrors of telescopes. The alloy of gold with silver, in which there is only $\frac{1}{5}$ th part of silver, changes the colour of the gold very sensibly; and the alloy is employed for foldering gold, being more fusible than this metal.

GOLD, Physical properties of. *Gold, aurum*, a yellow metal, heavy, pure, ductile, malleable, and shining; and on those accounts, the most valuable of all metals. In fusibility it ranks between silver and copper; it is not oxydable by fusion in atmospheric air; nor is it acted upon by any of the acids, except the oxymuriatic and nitro-muriatic.

The yellow colour of gold is rendered paler by fusion with borax; but this may be prevented or corrected by fusion with nitre, or sal ammoniac. The colour of gold is heightened by an alloy of copper, and this property of copper has given rise to sundry processes for exalting the colour of this noble metal. Other metals render it paler. The alchemists call gold, *sol*, the sun; to denote its pre-eminence over the other metals, which are called by the names of the planets. Its symbol, or character, is O; which, in their hieroglyphical way of writing, denotes perfection, simplicity, solidity, &c.

The weight of gold is to that of water, according to some statements, as 19.637 to 1000. Fine gold, immersed in water, weighs nearly one nineteenth part less than in air, and consequently it is upwards of nineteen times heavier than its own volume of water. However, the specific gravity of gold, or its comparative weight with an equal volume of water, has been variously assigned: some have made it 19.637, others 19.640, and in the Swedish Transactions it is made no less than 20.000; that of water being 1000. Others again have made it as low as 18.75. But from the experiments of Mr. Ellicott, it does not appear to have exceeded 19.207; and from those of Dr. Lewis, on the purest gold, well hammered, its gravity is stated between 19.300 and 19.400. In all experiments of this kind, the result should be specified with an account of the sensibility of the balance, and the quality and warmth of the water. An increase of heat rarefying water more than it does gold, the

gold must turn out proportionably heavier than an equal volume of the expanded fluid; and this difference is more considerable than it has generally been supposed. From freezing to boiling water, or by an augmentation of heat equivalent to 180° of Fahrenheit's thermometer, Dr. Lewis found that a rod of gold was lengthened about one part in 700, and consequently its volume increased about one part in 233, while the volume of water is increased one twenty-sixth or more; hence it appears, that by an augmentation of 40° of the thermometer, or from a little above freezing to the summer heat, the volume of gold, if its expansion be uniform, is increased one part in 1048, and that of water one in 117; and the gravity of gold, weighed in the water so warmed and expanded, should be greater than when the gold and water are 40° colder, in the proportion of about 19.265 to 19.400: and this calculation gives a difference, in the gravity, of 0.034 for every 10° of the thermometer; but some trials seemed to make it greater. It has been imagined, that the comparative gravity of gold to brass weights, which are more than double in volume to an equal weight of gold, must be so far influenced by the variable gravity of the atmosphere, that there must be an advantage in buying gold by weight when the air is lightest. But Dr. Lewis observes, that this difference appears too inconsiderable to be regarded in a commercial view. For the loss of weight of the two metals in the air being as much less than their loss in water, as air is lighter than water; and air, if we admit the accuracy of the conclusion deduced from an experiment of Mr. Hawksbee, being in its lightest state about a 937th, and in its heaviest state about an 848th part of the weight of water; it will be found, on calculation, that the gold preponderates above the brass, in the heaviest more than in the lightest air, only by one part in 145,000, or one grain in about 302 ounces; which is a difference too minute to be sensible in the nicest balance. If the mean gravity of gold be reckoned 19.300, as a cubic inch of water weighs about 254 grains, a cubic inch of gold will consequently weigh about 4902 grains, or 10 ounces, 102 grains. The pound weight, or twelve ounces Troy, of gold, is divided into twenty-four carats. Dr. Lewis states the specific gravity of fine gold at 53° Fahrenheit, to be 19.376. According to Briffon the specific gravity of fine gold in ingot is 19.258, and when hammered 19.361. The specific gravity of gold made standard by British copper, was found by Mr. Hatchett (see Phil. Transf. for 1803) to be 17.281, when cast in an iron mould; but when the same was cast in sand, it was only 16.994. (See *SPECIFIC GRAVITY*.) The softness of gold, for it is nearly as soft as tin, and its toughness, adapt it for receiving the impressions of dies, and of course to be reduced to the state of coin, and for various other purposes in the arts. It is but slightly elastic and sonorous. With regard to tenacity, it is inferior to iron, copper, platina, and silver, and therefore the assertions of former chemists and philosophers have been contradicted by later experiments, for gold has been usually represented as the most tenacious as well as the most ductile of all metals. Its malleability and ductility are sufficiently evinced by the *GOLD-leaf* and *GOLD-wire*, which see. See also *DUCTILITY*.

The value of gold to that of silver, was anciently only as twelve to one. Indeed, this proportion varies as gold is more or less plentiful: for Suetonius relates, that Cæsar brought such a quantity of gold from Italy, that the pound of gold was only worth seven pounds and a half of silver. In our coinage, the value of fine gold to fine silver is nearly as 15½ to 1. (See *COIN* and *STANDARD*.) Sir Isaac Newton observes, in a representation to the lords of the treasury

in the year 1717, that in the mints of Spain and Portugal the value of gold is sixteen times that of silver; but that in those countries, payments in silver bearing generally a premium of six per cent. the proportion may be considered as fixed by commerce at 15, $\frac{1}{4}$ to 1; that in the other parts of Europe, the value of gold is at most fifteen, and in China and Japan but nine or ten times that of silver; so that gold is rated higher in England than in any other part of Europe, and higher in Europe than in the Eastern countries. Hence, in great measure, arise the profits of exchanging gold for silver in one place, and re-exchanging them in another; and hence the greater disparity between the relative quantities of gold and silver in one commercial nation than in another; this metal being brought in most abundance which is rated highest in proportion to the other, and that which is rated lowest being drained away. There are various ways of determining the fineness of gold; or the proportion of alloy which it contains. Those who are used to this business can judge nearly the proportion of alloy from the colour of any given mass, provided that the species of alloy be known. For the method of doing this, see *Touch-neddles*. The great excess of the weight of gold, above that of the metals used for its alloy, affords another method of determining the quantity of alloy in any given mass, where the species of alloy is known. Thus fine gold loses in water one grain in every 19.3 nearly; and fine silver loses one grain in about eleven; from whence it is easy to find the loss of any number of grains of each, and consequently of any assignable mixture of the two metals. Thus, fifty grains of gold will lose above $2\frac{1}{2}$, and fifty grains of silver somewhat more than $4\frac{1}{2}$; so that a mixture of equal parts of the two will lose above seven in a hundred, or one in fourteen. A mixture of gold with half its weight of silver will lose one part in 15.4; with a third of silver, one in 16.2; with a fourth, one in 1.67; and with an eleventh of silver, which is the standard proportion of alloy, one in 18.1. On this principle, the specific gravity or proportional loss in water, of gold alloyed with different quantities of silver, copper, and mixtures of both, may be computed and formed into tables for use. The accuracy of this method, it should be observed, depends on the supposition that each of the two metals, that are melted together, retains its own proper gravity, which is the case in mixtures of gold and silver; but gold and copper, melted together, are specifically lighter than if they were weighed separately; or the specific gravity of the alloy is less than that of the mean of its ingredients; the case is the same with the alloys of nickel and gold, of lead and gold, of iron and gold; but the reverse happens in mixtures of gold with zinc, bismuth, and tin. It appears, therefore, that the hydrostatic balance cannot discover, with certainty, the exact fineness of gold, unless when silver is the metal mixed with it.

There are various methods of separating gold from gilt works: it may be separated from the surface of silver, either by spreading over the gilt silver a paste made of powdered sal ammoniac moistened with aquafortis, and heating it till the matter smokes, and is nearly dry; throw it into water, and the gold will easily come off by rubbing it with a scratch brush: or, by putting the gilt silver into common aqua regia, nearly boiling, and turning the metal frequently, till it becomes all over black; then wash it with water, and rub it with the scratch brush, which will disengage the gold left by the aqua regia. See *GILDING*.

Gold may be separated from gilt copper, by applying a solution of borax to the gilt parts with a pencil, and sprinkling over the place thus moistened a little powdered sulphur; when the piece is made red-hot and quenched in water, the gold may be wiped off with a brush.

Gold may be recovered from wood, gilt on a water size, by steeping it for a quarter of an hour in a quantity of very hot water, sufficient to cover it; then scrub the wood in a little warm water, with short stiff bristle brushes of different sizes: boil the whole mixture of water, size, gold, &c. to dryness; make the dry matter red-hot in a crucible to burn off the size, and grind the remainder with mercury. The gold will be more easily laid hold of by the mercury, by the addition of some clean sand.

GOLD, Alchemical History of. See *PHILOSOPHER'S Stone*, and *TRANSMUTATION*.

GOLD, Amalgam of, is a preparation of gold much used by the gilders (see *GILDING*); and it is made by heating some pure quicksilver in a clean crucible, and adding to it, when it is nearly boiling, about a sixth of its weight of fine gold in thin plates that are hot; after this mixture has been kept hot for a few minutes, it becomes an homogeneous substance; and when cold, it is put into a piece of soft leather, and which is gradually pressed till the fluid part of the amalgam, consisting almost wholly of mercury, is forced through the pores of the leather; while the gold, combined with about twice its weight of mercury, will remain in the state of a yellow silvery mass, of the consistence of soft butter; when this mass has been bruised in a mortar, or shaken in a phial, with repeated portions of salt and water, till the water receives no foulness from it, it is fit for use, and may be preserved for any time in a corked phial. For the purposes of gilding it is of great importance, that this amalgam should be formed of pure materials, as any portion of lead or bismuth would deteriorate the colour of the gold, and tarnish it with black specks. The mercury should therefore be previously distilled from the red precipitate (nitrous red oxyd of mercury), either alone or mixed with a little charcoal powder. See *AMALGAM* and *MERCURY*.

GOLD-beating, and GOLD-beater's skin. See *GOLD-leaf*.

GOLD, Burnished, is that which is polished with a steel instrument, called a burnisher, if it be wrought gold, or gilding on metal; or with a wolf's tooth, if it be gilding in water. See *GILDING*.

GOLD Chain. See *CHAIN*.

GOLD Coin, or species of gold. See *COIN* and *COINAGE*.

GOLD Colour on Glass and China. See *GEMS, GLASS, GILDING, and PORCELAIN*.

GOLD-coloured Glazing. See *GLAZING*.

GOLD-coloured Metal is produced by melting zinc with copper. According to the purity of the zinc and copper, the proportions in which they are mixed, and the intimacy of their union, the compound metal proves more or less malleable, and approaches more or less to the colour of gold. Some direct the zinc to be taken only in a fifth or sixth part of the weight of the copper, and others in an equal weight or more. Dr. Lewis observes, from the result of many experiments, that both with the smallest and largest of these quantities of zinc, the metal proves more like gold than with the intermediate proportions.

The colour of these compounds is improved by a small mixture of some other metallic bodies. Cramer recommends the addition of a small quantity of pure tin to copper, melted with a fourth or sixth part of zinc, which forms a compound metal, that acquires, on being well cleaned, and laid in the air for some days, a superficial colour of fine gold. Geoffroy says that iron has the best effect: with the proportions of ten parts of zinc, eight of copper, and one of iron-silings, he produced a metal of a fine smooth grain, compact, hard, and bright, and of a beautiful gold colour. By making the copper first into brass, and then melting it with a suitable quantity of zinc, a metal may be obtained of su-

perior quality to that produced either by melting the copper and zinc, or by impregnating the copper with zinc, by cementation and fusion with calamine; which is a method sometimes practised. A very ingenious artist, says Dr. Lewis, who now prepares a gold-coloured metal in great perfection, has a fine kind of brass made on purpose for this use. The union of the copper and zinc in fusion, succeeds best and with least loss of the zinc, according to Dr. Lewis, by using a mixture of black flux and borax, or a composition of twelve parts of green glass powdered, six parts of potash two of borax, and one of powdered charcoal: when this flux is fused in the crucible, the copper and zinc are dropped into it; and when they appear perfectly melted, they are to be well stirred together with an iron rod, and expeditiously poured out. The same flux will serve for melting several fresh quantities of the metal. Dr. Hooke gives the following receipt for making a gold-coloured metal: eight parts of distilled verdigris, *i. e.* of verdigris purified by solution in distilled vinegar and crystallization, and four parts of Alexandrian tutty, with two of nitre, and one of borax, are directed to be mixed with oil to the consistence of pap; then melted in a crucible, and poured into a flat mould first well warmed. A composition of this kind is called *aurum sophisticum*.

The following method is recommended by Homberg for giving a gold colour to copper, without the addition of zinc; make an amalgam of one part pure copper, and three parts quicksilver; boil this in river-water for two hours, then distil off the quicksilver in a retort, and cohobate it once; take out the copper and fuse it, and it will be found of a beautiful gold colour, more ductile than common copper, and extremely well fitted for watch-work, gilding, and the finer machines and utensils. The celebrated Mr. Pott affirms that a gold-coloured metal may be made from a mixture of copper and tin, and directs it to be compounded in the following manner: Take one half ounce of tin ashes, and four half ounces of copper; melt them well together in a close luted crucible, with a strong fire; or take one half ounce of the purest tin cut in pieces, and sixteen half ounces of pure copper beaten into thin plates; lay the tin between the copper-plates, lute the crucible close, and melt with a strong fire. See *Prince's METAL and TOMBAC*.

Silver is tarnished superficially, by certain vapours, as that of putrid urine, to a colour so like that of gold, that several edicts have been issued in France to prevent frauds of this kind with regard to wire and laces.

GOLD-coloured Pigments. See *PIGMENTS*.

GOLD-coloured Varnish. See *LACQUER*.

GOLD, Crown. See *COIN* and *STANDARD*.

GOLD, Dutch, is a kind of leaf used in gilding, &c. which is copper gilt, or brass beaten into leaves like the genuine gold-leaf. It is said to be made from copper-plates, by cementation with calamine, without subsequent fusion. The thickness, compared with that of leaf-gold, is as nineteen to four, and under equal surfaces it is considerably more than twice as heavy as the gold.

GOLD, Farthing of. See *FARTHING*.

GOLD, Fine or Pure, is that purged by the fire of all its impurities, and all alloy. The Latins call it *aurum purum*, *aurum primum*, *aurum obrium*, *aurum colum*.

The moderns frequently call it *gold of twenty-four carats*; but, in reality, there is no such thing as gold so very pure; and there is always wanting at least a quarter of a carat. Gold of twenty-two carats has one part of silver, and another of copper: that of twenty-three carats has half a part, *i. e.* half a twenty-fourth of each.

Bouteroue maintains, that the electrum of the ancients

was gold of nineteen carats; or four parts gold, and a fifth silver.

From an ordinance of king John of France, it appears that the gold then struck at Paris was of nineteen carats one-fifth; and yet it is added that it was the best and finest gold then known on earth. See *STANDARD*.

GOLD, Fulminating, aurum fulminans, a precipitate of gold from its nitro-muriatic solution by ammonia, which possesses a most remarkable explosive property. See *AURUM*.

It is prepared by diluting a solution of muriated gold with six or eight times its bulk of distilled water, adding drop by drop liquid ammonia, till the precipitation ceases; then let the yellow powder thus obtained be separated by a filter, well washed in hot water, and afterwards dried. The fulminating gold, thus procured, will exceed the weight of the original gold by about 33 parts in 100. If a small quantity, *e. g.* half a grain, of this powder be held over a candle, in a spoon or on the blade of a knife, it presently explodes with a very loud report. This powder should be very cautiously used; the temperature requisite for its explosion is stated at above 250° of Fahrenheit. Before it explodes, its yellow colour changes to black, and at the moment of its decomposition an instantaneous flash is observed. The principal energy in explosion is directed downwards, inasmuch that two or three grains of it exploded on a moderately thick sheet of copper will burst a hole in it. This salt is decomposed by an electrical shock, but it cannot be ignited by a spark from electricity or from flint and steel. It will vehemently explode by sudden friction, and therefore, in order to avoid dangerous accidents of this kind, it should never be kept in a ground-stoppered bottle. The facility of its explosion is very much increased by high drying; so that if it be heated till it becomes black, and is immediately removed from the fire, it will frequently go off by a mere touch. If the fulminating gold be mixed with four or five times its weight of chalk, or sulphat of potash, or with any pulverulent substance neither fusible nor decomposable at a moderate temperature, and exposed gradually to a low heat, it will be quickly decomposed, leaving merely the purple oxyd of gold. The same effect may be produced by very cautiously heating the fulminating gold without any addition, removing it from the fire when it has changed its colour, and when cold heating it again, and proceeding in this way till the powder becomes purple, in which state it will have entirely lost its explosive faculty. A similar change occurs by melting sulphur at the lowest possible heat, and dropping in the fulminating gold by half a grain at a time, well mixing it; the sulphur may then be burnt off without danger, and minute grains of metallic gold will be left behind. "The true theory of the decomposition of fulminating gold was partially discovered by Bergman, and has since been fully illustrated by Berthollet. The former of these able chemists shewed that this salt, when decomposed in close vessels was reduced to gold, partly in the metallic state and partly in that of purple oxyd, and at the same time a gas was extricated in bulk about a thousand times as great as that of the original fulminating salt, and which extinguished flame and animal life, was not absorbed by water, and gave no precipitate with lime-water. Berthollet, by decomposing the same substance in a copper tube, connected with a jar inverted in mercury, obtained azotic gas and a few drops of water, and the gold was reduced to the metallic appearance. Now as ammonia is composed of hydrogen and azot, and as the affinity of gold for oxygen is very slight, it is manifest that the decomposition and explosion, under the circumstances already mentioned, are occasioned by the oxygen of the

gold and the hydrogen of the ammonia combining to form water, and to the liberation of the azot and its sudden assumption of the gaseous state." Aikin's Dict.

GOLD, Leaf, or beaten gold, is gold beaten with a hammer into exceedingly thin leaves. It is astonishing to consider the fineness to which a body of gold is thus reduced. In an experiment of Reaumur's, forty-two square inches and three tenths of gold-leaf weighed one grain Troy; and Mr. Boyle found that fifty and seven tenths weighed but a grain. As a cubic inch of gold weighs 4902 grains, the thickness of the gold-leaf examined by the one was the 207355th, and of that by the other only the 248532nd part of an inch. See *DUCTILITY of Gold*.

This gold is beat on a smooth block of black marble, from two hundred to six hundred pounds in weight, and about nine inches square on the upper surface, fitted into the middle of a wooden frame, about two feet square, so as that the surface of the marble and frame form one even plane. Three of the sides are furnished with a high ledge, and the front, which is open, has a leather flap fastened to it, which the gold beater uses as an apron, for preserving the fragments of gold that fall off. Three hammers are employed in this business, having two round and somewhat convex faces: the first, called the cutch hammer, is about four inches in diameter, and weighs fifteen or sixteen pounds: the second, called the shoddering hammer, weighs about twelve pounds, and is about the same diameter: the third, called the gold or finishing hammer, weighs ten or eleven pounds, and is nearly of the same width. The French use four hammers, differing both in size and shape from those of our workmen.

The gold beaters also use three kinds of animal membranes; some of which are laid between the leaves to prevent their uniting together, and others over them to defend them from injury by the action of the hammer. For the outside cover, they use common parchment made of sheep skin; for interlaying with the gold, first, the smoothest and closest vellum made of calves skin; and afterwards, the much finer skins of ox-gut, stript off from the large straight gut slit open, prepared on purpose for this use, and hence called *gold-beater's skin*. The general process of their preparation, is said to consist in applying one upon another, by the smooth sides, in a moist state, in which they readily cohere and unite inseparably, stretching them on a frame, and carefully scraping off the fat and rough matter, so as to leave only the fine exterior membrane of the gut; beating them between double leaves of paper, to force out the remaining unctuousity; moistening them once or twice with an infusion of warm spices, and lastly, drying and pressing them. It is said, that some calcined gypsum, or plaster of Paris, is rubbed with a hare's foot, both on the vellum, and ox-gut skins, which fill up their pores, and prevent the gold leaf from sticking. These skins, after seventy or eighty repetitions, become unfit for use; but their virtue may be restored by interlaying them with leaves of paper moistened with vinegar or white wine, beating them for a whole day, and afterwards rubbing them over with plaster of Paris; and even holes in them may be repaired by the dextrous application of fresh skins.

GOLD, the manner of preparing and beating They first melt a quantity of the purest gold in a black-lead crucible, with some borax, in a wind furnace, and pour it into an iron ingot mould, six or eight inches long, and $\frac{1}{4}$ of an inch wide, previously greased and heated; the bar of gold is made red-hot and forged on an anvil into a long plate, which is farther extended, by being passed repeatedly between polished steel rollers, till it becomes a ribband, as

thin as paper. This ribband is divided by compasses, and cut with shears into equal pieces, which are forged on an anvil till they are an inch square, and afterwards well annealed. Two ounces of gold, which is the quantity melted at a time, make a hundred and fifty of these squares, so that each of them weighs six grains and two fifths; and as 4902 grains of gold make a cubic inch, the thickness of the square pieces is about the 766th part of an inch. All these squares are interlaid with leaves or vellum, three or four inches square; one leaf being laid between every two of them, and about twenty more of the leaves are laid on the outsides: over these is drawn a parchment case open at both ends, and over this another, in a contrary direction, so that the vellum and gold leaves are kept tight and close. The whole is then beaten with the heaviest hammer, till the gold is stretched to the extent of the vellum: the pieces taken out of this case or mould, are cut in four with a steel knife; and the six hundred pieces thus produced are interlaid, in the same manner, with pieces of the ox-gut skins, five inches square. The beating is repeated with a lighter hammer, till the golden plates have acquired the extent of the skin; when they are divided into four, by a piece of cane cut to an edge. The whole number of leaves is then divided into four parcels, which are interlaid, as before, and beaten separately, till they are stretched for the third time to the size of the skins. The French repeat the division and beating once more. After the last beating, the leaves are taken up by the end of a cane instrument, and being thrown flat on a leathern cushion, are cut to a size, one by one, with a square frame of cane made of a proper sharpness, or with a frame of wood edged with cane. They are then fitted into books of twenty-five leaves each, the paper of which is well smoothed, and rubbed with red bole to prevent their sticking to it. The size of the French gold leaves is from somewhat less than three inches to $3\frac{1}{4}$ square; that of our's from three inches to $3\frac{1}{2}$. We shall here observe, that the gold used for the above purpose is never pure, because pure gold is too ductile to be worked between the gold-beater's skins. The newest skins will work the finest gold, and make the thinnest leaf, because they are the smoothest. Old skins, being rough or foul, require coarser gold. The finest gold for this purpose has three grains of alloy in the ounce, and the coarsest 12 grains. In general the alloy is six grains, or one eightieth part. The alloy of leaf-gold is silver, or copper, or both, and the colour is produced of various tints accordingly. Two ounces and two pennyweights of gold are delivered by the master to the workman, who, if very skilful, returns 2000 leaves, or 80 books, of gold, together with one ounce and six pennyweights of waste cuttings. Hence one book weighs 4.8 grains; and as the leaves measure 3.3 inches in the side, the thickness of the leaf is one two hundred and eighty-two thousandth part of an inch.

The French prepare what is called green gold-leaf, from a composition of one part of copper and two of silver, with eighty of gold; but Dr. Lewis observes, that such an admixture gives no greenness to gold, and that this kind of leaf is made from the same fine gold as the highest gold-coloured sort, the greenish hue being a superficial teint given to the gold in some part of the process: this leaf is chiefly used for the gilding of books. A kind of leaf, called *party-gold*, is formed by laying a thick leaf of silver, and a thinner one of gold, flat on one another; they are then heated and pressed together, so as to unite and cohere: and being beaten into fine leaves, as in the foregoing process, the gold, though only in quantity a fourth

of that of the silver, extends over it and every where covers it.

GOLD, *Million of*, a phrase often used to signify a million of crowns.

GOLD Money. See **MONEY** and **COIN**.

GOLD, *Mosaic*, is gold applied in pannels on proper ground, distributed into squares, lozenges, and other compartments; part of which is shadowed to raise or heighten the rest. See **MOAIC**.

GOLD Plates for Enamelling are generally made of ducat gold, whose fineness is from $23\frac{1}{2}$ to $23\frac{3}{4}$ carats: and the finest gold is the best for this purpose, unless where some parts of the gold are left bare and unpolished, as in watch-cases, snuff-boxes, &c. for which purpose a mixture of alloy is necessary, and silver is preferred to copper, because the latter disposes the plates to tarnish, and turn green. See **ENAMELLING**.

GOLD, *Potable, aurum potabile*. See **AURUM Potabile**, and **GOLD**.

GOLD Powder, for the purposes of gilding, may be made by grinding gold leaf with honey, or thick gum-water, (see *Shell-gold*): by distilling to dryness a solution of gold in aqua regia: by evaporating the mercury from an amalgam of gold, taking care well to stir the mass near the end of the process with a glass rod or tobacco pipe; or by precipitating gold from its solution in aqua regia by applying to it a solution of common green vitriol in water, or some copper, &c.

GOLD Precipitate with Tin, called also, from its supposed discoverer, *calx Cassii*, is prepared with great care both in dissolving the tin, and diluting the solution. For this purpose, a mixture of two parts of aquafortis, and one of spirit of salt, is supposed to be the best menstruum for the tin. Into this mixture some fine block tin, granulated, is to be let fall, grain by grain, waiting till one grain is dissolved before another is dropped in, that the dissolution may go on slowly, without any heat or discharge of fumes. The gold is dissolved in common aqua regia; and a few drops of this solution being mixed with some ounces of pure water, as many drops of the solution of tin are added. If the mixture changes immediately to a clear bright purplish red colour, the due degree of dilution has been determined; if the colour appears dull, a greater quantity of water must be added for the rest of the solutions. After the mixture has deposited its red matter, and become clear, a little more of the tin solution is to be dropped in, for discovering and precipitating any gold that may still remain in it; the liquor being then poured off, the precipitate is washed and dried. Lewis's Com. Phil. Techn. p. 176. See **RUBY GLASS**.

GOLD, Queen. See **QUEEN gold**.

GOLD, Shell, is that used by the gilders and illuminers, and with which gold letters are written. It is made by grinding gold leaves, or gold beater's fragments, with a little honey, and afterwards separating the honey from the powdered gold by means of water. When the honey is washed away, the gold may be put on paper, or kept in shells; whence its name. When it is used, it is diluted with gum-water, or soap-suds. The German gold-powder, prepared from the Dutch gold leaf in the same manner, is generally used, and when it is well scoured with varnish, answers the end in japanner's gilding, as well as the genuine. See **GILDING**.

GOLD-size for burnished gilding, is prepared of one pound and a half of tobacco-pipe clay, half an ounce of red chalk, a quarter of an ounce of black lead, forty drops of sweet oil, and three drams of pure tallow; grind the

clay, chalk, and black-lead separately, very fine in water; then mix them together; add the oil and tallow, and grind the mixture to a due consistence; or it may be more simply prepared by grinding together some strongly calcined red ochre with the thickest and oldest drying oil that can be procured; and, previously to use, mixing it with a little oil of turpentine for giving it a proper consistence. See **OIL GILDING**.

GOLD-size of Japanners may be made by pulverizing gum animi and asphaltum, of each one ounce; red-lead, litharge of gold, and umbre, of each one ounce and a half, mixing them with a pound of linseed oil, and boiling them, observing to stir them till the whole be incorporated, and appears, on growing cold, of the consistence of tar; strain the mixture through a flannel, and keep it stoppered up in a bottle, for use. When it is used, it must be ground with as much vermilion as will give it an opaque body, and diluted with oil of turpentine, so that it may be worked freely with the pencil. A simple preparation consists of one pound of linseed oil, and four ounces of gum animi; powder the gum, and mix it gradually with the boiling oil: let it continue to boil, till it becomes of the consistence of tar; strain it through a coarse cloth, keep and use it as the other.

GOLD-smith, or as some choose to express it, *silver-smith*, the artist who makes vessels, utensils, and ornaments in gold or silver. The goldsmiths work is either performed in the mould, or beat out with the hammer or other engine. All works that have raised figures are cast in moulds, and afterwards polished and finished; plates or dishes of silver or gold are beat out from thin flat plates, and tankards and other vessels of that kind are formed of plates foldered together, and their mouldings are beat, not cast. The business of the goldsmith formerly required much more labour than it does at present, for they were obliged to hammer the metal from the ingot to the thinness they wanted: but there are now invented flattening-mills, which reduce metal to the thinness that is required, at a very small expence. The goldsmith is to make his own moulds, and for that reason ought to be a good designer, and have a taste in sculpture: he also ought to know enough of metallurgy to be able to assay mixed metals, and to mix the alloy.

The goldsmith in London employs several hands under him for the various articles of his trade. In this great city there are always hands that excel in every particular branch of the trade, and there is commonly employment enough for every one in his particular branch. The jeweller, the snuff-box and toy-maker, the silver turner, the gilder, the burnisher, the chaser, the refiner, and the gold-beater, are all employed by and under the goldsmith,

GOLD-smith, Company of, in London. See **COMPANY**.

GOLD Thread, or *spun gold*, is a flattened gilt wire, wrapped or laid over a thread of yellow silk, by twisting it with a wheel and iron bobbins. By means of a curious but complex machinery, a number of threads is thus twisted at once by the turning of one wheel. The principal art consists in so regulating the motion, that the several circumvolutions of the flattened wire, on each thread, may just touch one another, and form, as it were, one continued covering. At Milan, it is said, they make a sort of flattened wire, gilt only on one side, which is wound upon the thread, so that only the gilt side appears. There is also a gilt copper wire, made in the same manner as the gilt silver, chiefly at Nuremberg: and the ordinances of

France require it to be spun on flaxen or hempen threads. The Chinese, instead of flatted gilt wire, use slips of gilt paper, which they interweave in their stuffs, and twist upon silk threads.

GOLD, Tun of, is a kind of money of account, formerly used by the Dutch, and in some other countries, containing a hundred thousand florins.

A hundred pounds of, or in, gold, is found to weigh two pounds ten ounces: the sum in silver weighs twenty-six pounds four ounces. Twenty-two pence in copper farthings and half-pence, weigh one pound avoirdupois. A tun of gold, at 4*l.* the ounce, amounts to 96,000*l.* A tun of silver, at 5*s.* 2*d.* the ounce, to 6200*l.* A pound sterling of gold to 48*l.* An ounce is worth 4*l.* The penny-weight 4*s.* One grain, 2*d.* A pound of sterling silver amounts to 3*l.* 2*s.* An ounce is worth 5*s.* 2*d.* The penny-weight, 3*d.* and something more; one grain a half-penny. A pound of silver avoirdupois comes to 3*l.* 5*s.* 3*d.* half-penny.

GOLD, Virgin, is pure gold, just as it is taken out of the mines, before it has undergone any action or preparation of fire; whence the Greeks call it *αυρος*.

Such is the *αυροχυσος*, or gold-dust, and that got by lotion in the lavaderos in Chili: it is added, that there are masses or lumps of pure gold found in the mines, particularly those of Hungary. Accordingly, in the emperor's collection, are still preserved several plates of gold, said to have been thus found.

Virgin gold is sometimes very pale, and so soft, that it may be moulded into any figure with the hand; it even takes an impression from a seal, like the softest wax. To harden it, as also to heighten its colour, they mix emery with it.

GOLD, White. See PLATINA.

GOLD Wire is a cylindrical ingot of silver, above an inch thick, two feet in length, and weighing about twenty pounds, superficially gilt, or covered with gold at the fire, and afterwards drawn successively through a great number of little round holes of a wire-drawing iron, each less than the other, till it be sometimes no bigger than a hair of the head. There is very little wire made entirely of gold, and this chiefly for one particular purpose, that of filligree work.

It is amazing to what degree of fineness the gold is here drawn; and yet it still keeps firm together, and never shews the least signs of the silver underneath it. The reader may see a computation hereof, as also a more particular account of the manner of proceeding, under the article DUCTILITY of gold.

GOLD Wire flatted, is the former wire flatted between two rollers of polished steel, to fit it to be spun in silk, or to be used flat as it is without spinning, in certain stuffs, laces, embroideries, &c.

Manner of forming Gold Wire and Gold thread, both round and flat—The first object, which is of the utmost consequence, is the choice of the purest gold; for on this chiefly depends the beauty and durability of the colour of the laces, brocades, and other commodities prepared from it. To a difference in this respect, the boasted superiority of the French laces to the generality of those made in England, till of late, has been wholly owing. With regard to the silver that forms the body of the wire, it is said that there is an advantage in its being alloyed. The French silver for gilding is said to be alloyed with five or six penny-weight, and ours with twelve penny-weight of copper, in the pound Troy. The gold is employed in thick leaves,

which are applied all over the silver rod, and pressed down smooth with a steel burnisher. Several of these leaves are laid over one another, as the gilding is required to be more or less thick. The smallest proportion allowed by act of parliament, is 100 grains of gold to a pound, or 5760 grains of silver. The largest proportion for the best double gilt wire was formerly 120 grains to a pound; but the proportion of gold has been of late increased to about 140 grains. The first part of the drawing process, as well as the preparation and gilding of the silver rod, is performed by the refiner, who uses plates of hardened steel, with a piece of tough iron welded on the back, to prevent the steel from breaking. The holes in these plates are conical, being larger in the back part than in the steel, that the rod may not be scratched against the outer edge, and that they may contain bees-wax, which makes the rod pass more freely, and preserves the gold from being rubbed off. One end of the rod, made smaller than the rest, is pushed through a hole that will admit it, when the plate has been properly secured, and laid hold of by strong pincers, called clamps, adapted to the purpose; to these pincers, which are so contrived, that the force which pulls them horizontally, serves at the same time to press them together, a rope is fastened by one end, and the other end goes round a capstan with cross bars, which requires the strength of several men to turn it. The rod, thus drawn through, is well annealed; it is then passed through the next hole; and the annealing and drawing are repeated, till, being reduced to about the size of a large quill, it is delivered in coils to the wire-drawers. The remainder of the process requires plates of a different quality, which are brought from Lyons in France, and are formed of a metallic mass, whose prevailing ingredient is iron: the holes are drilled in them here. These plates are of two sorts; some of considerable thickness, for the wire in its larger state, and others about half as thick, for the finer wire. In the use of these plates, furnished with a variety of holes, the dexterity of the workman principally consists in adapting the hole to the wire: for this purpose he uses a brass plate, called a *size*, on which is measured, by means of notches, like steps cut at one end, the increase which a certain length of wire should gain in passing through a fresh hole; and if the wire is found to stretch too much or too little, the hole is widened or contracted. Slits of different widths, in thick polished iron rings, serve also as gages for measuring the degree of fineness of the wire.

The wire-drawer's process begins with annealing the large wire received from the refiner, which he does, by placing it, coiled up, on some lighted charcoal, in a cylindrical cavity, called the pit, under a chimney, and throwing more burning charcoal over it. When it is cooled by being quenched in water, one end is passed through the first hole in the thick plate, and fastened to an upright wooden cylinder six or eight inches in diameter; in the top of which are two staples, and through these is passed the long arm of a handle, by which the cylinder is turned on its axis by several men. By this process, called *degrossing*, the wire is frequently annealed and quenched, after passing through every hole, or every other hole, till it is brought to about the size of the small end of a tobacco pipe, and then cut into portions for the fine wire-drawer. In this last part of the wire-drawing process, annealing is not necessary, but the wire is waxed at every hole. The contrivance for drawing the wire through the plate in this case, when less force is needful, is a kind of a wooden wheel placed horizontally, having in its upper surface small holes at different distances from the axis, into one or other of which, according to the force required,

is inserted the end of an upright handle, whose upper end is received in a hole made in a cross bar above. From this the wire is wound off upon a smaller cylinder, called a rochet, placed on the spindle of a spinning-wheel; and this cylinder being placed behind the plate, the wire is again drawn through upon the first, and being brought to the proper fineness, it is annealed for the flattening-mill. In this annealing, the wire is wound on a large hollow copper bobbin, set upright, including small-coal, and encompassed with lighted charcoal or small-coal, communicating a gradual heat. The wire, in this state, must be watched and removed from the heat, when it appears of the proper colour. The next operation is that of the flattening-mill, which consists of two perfectly round and exquisitely polished rollers, formed internally of iron, and wetted over with a plate of refined steel; these rollers are placed with their axes parallel, and their circumferences nearly in contact; they are both turned with one handle; the lowermost is about ten inches in diameter, the upper little more than two, and their width or thickness is about an inch and a quarter. These rolls are sometimes repolished with putty, prepared by calcining a mixture of lead and tin. The wire,

unwinding from a bobbin, and passing between the leaves of a book gently pressed, and through a narrow slit in an upright piece of wood, called a ketch, is directed by a small conical hole in a piece of iron, called a guide, to any particular part of the width of the rollers, some of the best of which are capable of receiving, by this contrivance, forty threads. When the wire is ^{drawn}attened between the rollers, it is wound again on a bobbin, which is turned by a wheel, fixed on the axis of one of the rolls, and so proportioned, that the motion of the bobbin just keeps pace with that of the rolls. Dr. Halley states that six feet in length of the finest gilt wire before flattening will counterpoise no more than a grain; and as the gold is not quite 1-57th of the whole, a single grain of gold thus extended will be 345.6 feet long. By flattening, the length of the wire is increased about one-seventh, and its weight is equal to 1-96th of an inch; hence the surface occupied by one grain is equal to 98.7 square inches, with a thickness of 1-490444th of an inch. (See DUCTILITY.) See on the subject of the preceding articles, Macquer's Dict. of Chemistry, Eng. edit. 1777. and particularly Dr. Lewis's Philosophical Commerce of Arts, *passim*. See also Aikin's Dictionary.

Grand Junction Canal

GRAND Junction Canal. To the full account which we gave of this very important inland navigation in our article CANAL, we have here merely to add a few particulars which have occurred since that account was printed. The act of the 50th Geo. III. for the Grand Union canal provides, that a canal with locks is to be substituted for the railway-branch from Gayton to Northampton, in order to open a communication by water, from the head of the new navigation, the design for the continuation of the Leicestershire and Northamptonshire Union canals further south than Market Harborough, where it now terminates, being dropt, in consequence of the adoption of the Grand Union above-mentioned, which will connect the above canal with the Grand Junction. The three aqueduct arches over the Ouse at Wolverton having been made flat elliptical, instead of the curves of equilibration, and the foundation also insufficient, they gave signs of great insecurity immediately on their centres being struck, and in February 1808 two of them actually fell in and emptied the canal, as far as the stop-gates: fortunately, the old line of locks across the valley had not been disturbed, and the trade has suffered no interruption in consequence. A cast-iron aqueduct on brick and stone piers is now substituting for these three arches, under the direction of Mr. Benjamin Bevan, who is now the engineer to the company. In 1807 a new reservoir was

completed near the side-ponds on the northern side of the Tring summit, for supplying water to the locks below the side-ponds in dry seasons.

In examining the strata and springs on the north side of the chalk summit, between Tring and Wendover, with a view to better supplying the Wendover branch and summit-level with water, Mr. Bevan discovered, that different water-tight beds in the lower chalk held up springs a considerable height above the canal, owing to their dip to the southward; and in order to avail himself of this water, a fough or tunnel was begun in the upper bank of the canal near Wendover, and has been driven about half a mile southward, intersecting different strata of chalk from beneath, and increasing in its supply of water as it proceeded; but observing that the principal vent of this water was in the winter and early spring months, when the other sources were more than sufficient for the supply of the canal, it occurred to that ingenious gentleman to place a strong and water-tight valve in the most favourable part of this tunnel, which, as soon in the autumn as the canal is amply supplied from its other feeders, is shut, and kept so, until these begin again to slacken in their supply; the water in the immense planes of these beds of chalk, in the mean time accumulating, as in a vast subterranean reservoir, the springs rise to the level which they originally did before this tunnel was begun, about 20 feet above the canal; and for many weeks

after the opening of the valve, in the beginning of summer, they pour forth a most surprising stream of water into the canal, which otherwise would have vented miles off in the chalk vallies, or slowly have made its way down through the joints and fissures in the strata to springs at the bottom of the chalk, which vent below the level of the canal.

In 1808 a twelve-horse single Bolton's steam-engine was erected near Nash-mill, in Hertfordshire, to lift the water again, the rise of four locks, for better supplying the mills during seven or eight months of the year. The company, in 1806, caused boats to be fitted up for conveying fat sheep alive, in tiers one above another, from distant places in the county, to the London markets, instead of fatiguing them by driving along the roads, the scheme of thus bringing oxen having been previously tried, and found not to answer; but after a fair trial, the expences were found to over-balance the advantages expected from this also; we are sorry also to add, that the cattle-market at Paddington has failed, and that the pens erected for it by the company have been sold and removed.

The limited quantity of coals brought to Paddington, or within 20 miles of London by this canal, now pay a duty of 10s. 9½d per ton (of 20 × 112lb.), which is equivalent to the duty on Newcastle coals in the Thames: in consequence of this heavy and oppressive duty, many waggons and carts are employed in fetching coals by land, from the next wharf beyond the limited distance, near Watford. The Grand Union canal above-mentioned is begun, and is to join this canal near the S.W. end of the Braunston tunnel. The design of a branch from near Tring, through Aylesbury and Thame, to the Thames and its navigation and Wilts and Berks canal near Abingdon, has been again revived, and it seems probable, that an act for that purpose will pass in the ensuing sessions of parliament (1811).

Towards supplying water to the inhabitants near Paddington, a transfer of the company's rights has been made to a separate water-company, which is expected to be confirmed by parliament in the ensuing sessions.

In November 1806, the company declared the first half yearly dividend of 1½ per cent. on the original shares, which has regularly increased to 3 per cent. half-yearly, exclusive of property tax. The affairs of the company seem now fast retrieving from the effects of their great mismanagement for many years after its establishment, and to be now in a very prosperous state; the shares (of 100l.) were, in September 1810, reported to be currently sold at 302l. each! although, at one period, the same could with difficulty be disposed of at 65l. to 70l. each: such are the effects of good or bad management, and of abilities and integrity in those entrusted with the direction and management of an immense concern like this, in inspiring confidence in commercial men to enter into trade and speculations connected with the canal, and in capitalists to invest their money in the company's shares. A resolution of the general assembly of proprietors, on the 7th of June 1803, for appointing a general superintendent of their concerns, principally led to this beneficial change. On the 11th of June following, Charles Harvey, esq. was appointed to this office by the committee, and, after much opposition from certain powerful individuals, was, on the 11th of July, confirmed therein, by a general assembly called for the special purpose.

GRAND Key, a small island among the Bahamas. N. lat. 26 54'. W. long. 77° 48'.

GRAND Lake, a lake of Louisiana. N. lat. 32°. W. long. 93° 5'.—Also, a lake in the province of New Brunswick, near the river St. John's, said to be 30 miles

long, eight or ten broad, and in some places 40 fathoms deep.

GRAND Luce, *Le*, a town of France, in the department of the Sarthe, and chief place of a canton, in the district of Saint-Calais; 14 miles S.E. of Le Mans. The place contains 2045, and the canton 10,493 inhabitants, on a territory of 227½ kilometres, in 8 communes.

GRAND Manan Island, an island of the Atlantic ocean; 6 miles S. by S.E. of Campo Bello island, opposite to Papamaquoddy bay on the eastern border of the United States.

GRAND Ridge, is a term often used, (see our article CANAL,) for the water-head, or summit line, across an island or continent, from whence the rain waters fall by opposite courses to the ocean. It results from the admirable system of vallies, which the great Creator has spread over the whole face of the earth, leaving no part, perhaps, originally of the surface, without a descent and out-fall to the sea; that the ridges, or summit-lines, form a system not less beautiful and perfect than the vallies; and whence it happens, that, from any hill whatever, it is practicable to mark on a good map, and to travel to every other hill in the same island or continent, however large, without crossing any running water, however small, but constantly to pass along a ridge or waterhead; whence the waters on the surface fall opposite ways from your route. It seems surprising, that no one has attempted to illustrate this subject by a good map, shewing all the connections and windings of these ridges in England, or even any local district, until of late, that Mr. Farey has prepared a square of map, including Derbyshire, shewing the ridges, and the situation of all the hills and principal eminences upon them, which is intended to accompany his report to the Board of Agriculture on that interesting district.

The triangular form of the British island, and the situation of the two principal rivers, the Thames and the Severn, (or rather the Bristol channel,) occasion the grand ridge of England to divide into two branches on the Chalk Downs, a few miles N.E. of Devizes; one of which, (the south-western,) proceeds to Rundaway-hill, and crosses the deep cutting of the Kennet and Avon canal, near to Devizes, near East Lavington, Warminster, Wincanton, Beamifler, Crewkerne, Chard, &c. by a most circuitous route, passing almost to the north and to the south coasts alternately, until it reaches the Land's End in Cornwall: having, in this long route, probably descended to no lower strata than the red ground or marle, of which we shall speak further presently.

The other, or south-eastern branch of the grand ridge, proceeds along the chalk and the clays and sands above it, across the deep-cutting of the Kennet and Avon canal, near Burbage, by High-clere, (near which it probably occupies the highest stratum in the whole British series,) near to Alton and Haslemere, when it soon descends off the chalk into the great southern denudation, (see Philosophical Magazine, vol. xxxv. p. 130.), and pursues the under measures, through the wealds of Sussex and Kent, by Alford, Leith-hill, Handcross, (on the London and Brighton roads, being there on the lowest stratum but one which appears in that road,) by Turner-hill, Nutley, Crowborough, Rotherfield, Wadhurst, Tenterden, Shadoxhurst, Lyme (near Hythe), where it again ascends the edge of the chalk, and proceeds on it by Paddlesworth, Swingfield, and Lydden, to the coast at King's Down, near Walmer castle.

From the point of branching, N.E. of Devizes, as above described, the grand ridge follows the chalk northward by White-horse hill, near Cleevehill, &c. till within a few miles

of Swindon, when it turns to the N.W., and descends to the marle, and other strata below the chalk, crossing the Woburn sand stratum, not far from Wooton-Basset: and, passing to the Bath free-stone range, it crosses the Salperton tunnel, on the Thames and Severn canal, and proceeds near to the western edges of the same strata, by Charlton-Kings, near Cheltenham, Stanway-hill, Broad-way-hill, Lemington-hill, Long-Compton-hill, and Epwell; soon after which, the grand ridge begins to leave the free-stone, and take to the dark blue clays, &c. under it, except crossing some points of the stone, and traverses the Fenny-Compton tunnel, on the Oxford canal; thence by Hellidon, and near Daventry, it crosses the Braunston tunnel, on the Grand Junction canal, at West-Haddon, and at Husband's-Bosworth, the tunnels of the Grand Union canal; when, turning north-west, the ridge passes Gilmorton; and not far from Lutterworth it crosses the Lias clays and lime-stone strata, and descends to the red marle (above mentioned), and quickly, by a great fault, or sudden lift of the strata, is brought upon the coal-measures of the Bedworth-field, and crosses the deep cutting of the Coventry canal, through Bedworth town, across the late Sir Roger Newdigate's canal, and sweeps round to the west, south-west, and south, to Kenilworth; when, having crossed another fault, and got again upon the red marle, it crosses the deep-cutting of the Warwick and Birmingham canal, near Baddesley-Clinton, and of the Stratford canal, near Hockley; thence by Ashley-heath, and crosses the West-heath tunnel of the Worcester and Birmingham canal, and the Lapal tunnel of the Dudley canal: after which, the grand ridge crosses the basaltic hills between Rowley and Dudley, (which belong to the red marle strata,) and, descending to the coal-measures, crosses the Dudley tunnel N.W. of that town, and proceeds by Sedgley; then crossing an erect and denudated patch of the yellow lime-strata, it crosses the deep-cuttings of the Old Birmingham canal, the Wyrley and Essington canal, and of the Staffordshire and Worcestershire canal, all near Wolverhampton town; then by Taterhall, Wrottesley, Blimhill, Cowley, Wooton, (near Eccleshall), Broughton, Ashley, Maer, Madeley-park, to Keefe, (near Newcastle-under-line,) where it has again got upon coal-measures, by Bignole-hill, and across the Harecastle tunnel, on the Trent and Mersey canal, by Golden-hill, Wickinstone rocks, and, crossing an immense fault, descends to the lime-stone shale, (see Mr. Farey's section in *Plate II.* vol. xxxi. of the *Philosophical Magazine*), on Biddulph Moor; thence passes the top of the Great Rudyard reservoir, to Gun-hill, and crossing to High Roches rocks, it there ascends the first grit; then crosses a small trough of the first coal-shale and second grit, and descends again to the first grit, or Ramshaw rocks, and still further, on the lime-stone shale, at the Royal Cottage, along which it proceeds to the N.W. side of Flash, and then ascends the first grit again, on South-Axe-edge-hill; it again descends to the shale lime-stone in crossing Middle and Great Axe-edge-hills; from whence it ascends across the first grit and first coal-shale, and ascends the second grit on Thatch Marsh; this it pursues to the north of the Macclesfield and Buxton road, and then turning N.E. again descends to the lime-stone shale, and follows it across the Manchester and Buxton road; soon after, it ascends the first grit and first coal-shale, on Comb's-moss, and again descends to the shale, passes Sitting-low, (1½ mile S.E. of Chapel-en-le-Frith,) when, turning eastward, it crosses the Great lime-stone fault, (N. of Dove-holes,) and is found upon the third lime-stone, on which it crosses the quarries and rail-way of the Peak-Forest canal; soon after, it passes over the basalt-edge of the third toad-stone,

and descends to the great fourth lime-stone in Peak-Forest, which is probably the *lowest* stratum, to which the grand ridge passes in its route through England; this lime-rock having been estimated to be four miles at least of perpendicular thickness below the top of the chalk, from whence we commenced our description; much the greater part of this vast series of strata having in this route along the grand ridge been lost suddenly by perpendicular lifts of the strata or faults, which, in proceeding to this point by more favourable routes, might have been seen baffling in succession. For about one and a half mile the ridge proceeds upon the fourth lime, then again ascends a point of the third toad-stone and third lime, to the village called Sparrow-pit, in the Manchester and Castleton road, where it again crosses the great fault and ascends to the lime-stone-shale on Rushop-edge, whence it proceeds northward, and after crossing the Bridle-road from Hayfield to Edale-chapel, it ascends the first grit on Edale rock, and proceeds across the mooses on Kinder-scout hills; these it leaves at their N.W. corner, and crosses the mooses on the shale, and the ancient Bridle-road called Doctor-Gate, from Glossop to Ashop-Dale; it then ascends the first grit again on shelf-stones, and follows the same to Wain-stones and Blakelow-stones, which seems to be the highest land in Derbyshire, it then passes N. E. by Round-hill, and ascends to the first coal-shale, crosses the Manchester and Penistone-road at Lady-crofts; where, turning N.W. it ascends the second grit rock, and proceeds by Dean and Bretland Edges, to cross the Glossop and Huddersfield road, on the bogs upon this rock on Holme moss; from hence the ridge, after some distance, again descends to the first coal-shale, the first grit, and to the limestone-shale, crossing the Stanage tunnel on the Huddersfield canal near Marsden; the ridge then proceeds across Black-stone-edge, and crosses the deep-cutting of the Rochdale canal, near the village of Huddersfield, (which has improperly been said in the population accounts of 1801, to be a town containing 10,671 persons!) the ridge then passes Holme on the Burnley and Halifax road, whence it proceeds, and near Colne comes again upon coal-measures, which are, however, lost again at the great fault, in which part of the Foulridge tunnel on the Leeds and Liverpool canal was driven, and which occasioned the extraordinary trouble and expence attending that tunnel, which is mentioned in our article CANAL. From hence the grand ridge proceeds, by Barnoldswick, West Marton, near the Cold-Comitara, E. of Settleton lime-stone, over Pen-nigant-hill, Snays-fell, Nine-standards, Kelton-fell, Lunc-forest, Scordal-head, Milbourn-forest, Aldstone-moor, (lime,) Hartside-cross, Gelfsdale-forest, Talkin, and crosses the Roman or Picts wall on the E. side of Upper Denton, and soon after it enters Roxburghshire in Scotland; through which it is much easier to trace this grand ridge than in England, it forming often the boundaries between the Scotch counties, to which this ridge and its collateral ridges are much better adapted than the rivers and brooks, which have generally been chosen as boundaries, both as being more permanent, and not liable to the changes which streams of water are undergoing in the bottoms of vales, and avoiding those disputes respecting, and the delay of making and improving bridges, fords, navigations, mills, &c. owing to the rivers being part in one county and part in another, and by which also many of the most considerable towns are split into two or more counties, to the no small inconvenience of their inhabitants, in judicial and other county matters.

—Also, a river of Sicily, which runs into the Mediterranean on the N. side of the island, N. lat. $38^{\circ} 3'$. E. long. $14^{\circ} 54'$.

—Also, a river of America, which runs into the Missouri, N. lat. $38^{\circ} 56'$. W. long. $93^{\circ} 25'$.—Also, a broad river of America, which discharges itself into lake Michigan, N. lat. $43^{\circ} 25'$. W. long. $85^{\circ} 35'$.—Also, a river of America, which runs into lake Erie, N. lat. $41^{\circ} 55'$. W. long. $81^{\circ} 8'$.—Also, a river of Canada, which runs into the Detroit, N. lat. $42^{\circ} 34'$. W. long. $82^{\circ} 42'$.—Also, a river of Canada, which runs into the St. Laurence, N. lat. $47^{\circ} 3'$.

• *GRAND River*, or *Rio grande*, a river of Africa, which runs into the Atlantic, near the Bissagos isles, N. lat. 11° . W. long. $14^{\circ} 30'$.

GRANDE Seaux, an Indian nation, inhabiting a territory of the Missouri, and able to furnish 800 warriors.

GRAND Surry-Canal. This canal is yet in the same state, nearly, as when our account of it in the article CANAL was written, in 1805, except, that about two miles in length of it, at its N. E. end, has been brought into use, since the Croydon canal has been completed; and that the dock for ships, at its entrance from the Thames, was completed and opened in June 1807, and has answered so well to the proprietors, that in the last sessions of parliament, they made an unsuccessful attempt to obtain power for a further extension of them. In February, 1809, this company determined on erecting a ten-horse steam engine on the banks of the canal, by the Deptford road, for supplying the neighbouring inhabitants with water, intending to let the surplus power of this engine to some manufacturers.

GRAND Traverse, a range of islands, consisting of huge rocks in lake Michigan.

GRAND Trunk Canal, is a name commonly applied to the Trent and Mersey canal, which see in our article CANAL.

GRAND Union Canal. In the sessions of parliament, 1810, (50 Geo. III.) an act passed for making the Grand Union canal, the general direction of which is about S. W. $23\frac{1}{4}$ miles, in the counties of Leicester and Northampton, being considerably elevated, and crossing the grand ridge of the island twice, by tunnels, its middle part for about half its length skirting near to the ridge on its western side, and the two ends being on the eastern side of the ridge. Its objects are the completing of the long-desired water-communication between the Trent river and the many canals which connect therewith, in Derbyshire, Nottinghamshire, and Leicestershire, and the Grand Junction canal, and

through it to the metropolis, without making the enormous circuit by Burton, Fradley-heath, near Litchfield, Tamworth, Atherstone, Nuneaton, and Braunstone, which at present goods, coming by water from Leicester, Nottingham, and Derby must do; it is intended also to supersede the necessity for the southern part of the Leicestershire and Northamptonshire Union canal, between Market-Harborough and Northampton, which on account of its difficulties has never been attempted; the present rail-way branch between the Grand Junction and Northampton is intended to be changed for a canal with locks, by which means the people of Northampton will have a water-communication with Market-Harborough, Leicester, &c. with only about 14 miles longer distance than the Leicestershire and Northampton Union would have been, if the same had been completed according to its original act. Market-Harborough and Daventry are the only considerable towns near the line of this canal, which commences in the Leicestershire and Northamptonshire Union canal near Gumley, and terminates in the Grand Junction canal near Buckby-wharf, near the S. E. end of the Braunstone tunnel. From Gumley in $\frac{1}{2}$ mile is a rise of 76 feet by 12 locks, and thence to Watford, 20 miles are level, then in $\frac{1}{2}$ mile is a fall of 53 feet by eight locks, and thence to the Grand Junction canal about three miles are level; near Husband's Bosworth is a tunnel of about 1120 yards long, and near Crick another of about 900 yards long. Near Crick it is proposed to make a reservoir of 60 acres above the canal, but below its level, so that the surplus water collected from other parts of the canal in rainy seasons can be here reserved, to be pumped up when wanted.

The width of the canal at top is 42 feet and 14 at bottom, and its depth of water five feet; the locks are 82 feet long and seven wide, calculated for 25 ton boats. This line was first surveyed by Mr. James Barnes in 1803, and by Mr. Benjamin Bevan in 1808 and 1809, and the latter is appointed engineer for the execution of the work.

GRAND Western Canal, is so denominated in an act which passed in the year 1796, as mentioned in our article CANAL, but under which no progress had then been made. In April 1810, it was reported, that a beginning had at length been made on the summit level, in Holcomb, Devon. A much larger canal, capable of conveying ships from the Bristol channel to the south coast, has been some time in agitation, for avoiding the very circuitous and tedious navigation round the Land's End; which, however desirable, is scarcely practicable, we incline to think, for want of water.

Graver

GRAVER, a steel instrument, serving to engrave on metals. The graver consists of four sides or faces, and the point usually terminates in a lozenge: in some it is round, and in others square. The round point is best for scoring lines, the square for cutting broad and deep, and the lozenge for more delicate and fine strokes and scratches. Le Boffe recommends those of a form betwixt the square and lozenge. See **ENGRAVING**.

The gravers should be made of the best steel, which must be drawn out into small rods with a charcoal fire. These rods, after having been cut into the proper lengths for gravers, should be softened, by heating them in a charcoal fire, and suffering them to cool very slowly: let them next be filed into the desired form, and brought back to a hard temper by heating them red-hot, and in this state dipping their ends into soft soap. This should be done in a perpendicular direction; for, if they be turned in the least degree obliquely, the graver will warp and be crooked.

If the temper of the graver be too hard after this treatment, and prevent the whetting it properly to an edge, it may be softened, by laying its end on a large burning piece of charcoal till it begins to grow yellow, and then thrusting it into a lump of tallow, or dipping it in water; but if water be used, the graver must not be too hot. It may be known whether the graver be tempered to a proper hardness by touching the edge of it with a file, which, if any effect attends it, proves the temper to be too soft. The best proof of too great hardness is the breaking of the point in engraving; after which, if a new edge be made by whetting the graver, it will be frequently found very good without any other alteration. *Handmaid to the Arts*, vol. ii. p. 56.

The other end is fitted into a wooden handle.

Besides engravers, the seal-cutters, lock-smiths, gun-smiths, gold-smiths, armourers, spurriers, &c. likewise make use of gravers.

Green

GREEN, 'one of the original colours of the rays of light. Grass and herbs, and even all vegetables in places exposed to the open air, are green; and those in subterraneous places, or places inaccessible to the air, white and yellow. Thus when wheat or the like germinates under-ground it is white or yellow; and when it is in the open air, green; though this too is yellow before it be green.

GREENS, *Artificial*, are very rarely simple colours, but produced by mixture of yellow and blue.

Two powders, the one blue, and the other yellow, well mixed, appear perfectly green; though, when viewed with a microscope, we observe a chequer of blue and yellow.

The tincture of red roses with oil of tartar per deliquium, or with spirit of sal ammoniac, produces green. The tincture of many red flowers is changed into green by an alkali. The tincture of red roses, and the yellow tincture of crocus, or the blue tincture of cyanus, and the white spirit of sal ammoniac, produce green. The solution of verdigris becomes colourless by the affusion of the spirit of nitre, and by the affusion of the oil of tartar it becomes green again.

As no vegetable has yet been discovered, which is capable of giving to cloth of any kind a permanent green colour, the dye for this purpose is a compound colour, formed in dye-vats either by putting a yellow on a blue ground, or a blue on the yellow ground, or by mixing the blue and yellow materials, and dyeing with them as with a simple colour. The common and most permanent green is given to woollen cloth in the following manner. The cloth, being first dyed blue in the indigo vat (see INDIGO), is then well scoured, and afterwards dyed in a bath of weld or any other yellow dye with alum and tartar, as in the mode of dyeing of simple yellows, except that the yellow materials are used in greater quantity than the yellow alone of equal body would require. Very deep greens are made to acquire a slight brown or kind of burnish by adding to the bath small quantities of log-wood and sulphat of iron. As for silks, they are first strongly alumed, then dyed yellow with weld, and afterwards finished in the indigo vat. Silk, cotton, and linen are dyed green in the same general mode, but with considerable variations in the different processes. The most beautiful green hitherto known, and which perfectly well resists the action of light and air, is given by the combination of Prussian blue and yellow, but this colour is destroyed by soap and alkalis. To cotton this colour is given, by first dyeing it olive with weld, or any other yellow dye, and a compound mordant of alum and iron, and then raising the green by prussiat of potash. (See PRUSSIAN blue.) Berthollet observes, that in the process for this purpose there seems to be a mutual distribution of the mordants and colours, the Prussian colour taking the iron and becoming blue, whilst the alum and weld remaining in the olive form a fast yellow, and unite with the blue into a fine green.

The only simple green in common use is that of the carbonated oxyd of copper precipitated from verdigris by an alkali. A solution of verdigris is made in vinegar, and a few hours before dyeing a solution of as much pearlash as verdigris is added to it, the mixture is heated, and the cotton, previously alumed, is passed through this bath. The colour then given is a soft apple-green. Aikin's Dict.

The dyers make divers shades, or casts of green, as *light green*, *yellow green*, *grass green*, *laurel green*, *sea green*, *dark green*, *parrot green*, and *coladon green*.

GREEN, *Brunswick*, is a pigment used by some of the German artists, which they prepare by adding to the saturated solution of one part of muriated ammonia in cold water, three parts of copper clippings; and by covering the glass vessel that contains it with gauze so as to keep out the dust, and placing it in a warm situation, so that the moisture may evaporate, which purpose will be effected in a few days. The muriat of ammonia soon begins to be decomposed by the copper, which is corroded and converted into a green oxyd. When the whole is evaporated to dryness, let it be digested in two or three successive portions of spirit of wine, as long as any green oxyd is taken up; then add the solutions together and expel the liquor by a gentle heat, the residue is a pure dark green sub-muriat of copper, known in the shops by the name of refined Brunswick green.

GREEN, *Mountain*, or *Hungary green*, is a sort of greenish powder found in little grains, like sand, among the mountains of Kernaufent in Hungary, and those of Moldavia. Though some hold, that this mountain green is factitious, and the same with that the ancients called *flos eris*, prepared by casting water, or rather wine, on copper red-hot from the furnace, and catching the fumes thereof on copper plates laid over for that purpose: or by dissolving copper-plates in wine, much as in making verdigris. The painters make use of this colour for *grass green*. It is sometimes counterfeited by grinding verdigris with cerusa.

GREEN, *Calcined*, and *distilled green*. See VERDIGRIS.

GREEN, *Prussian*. See the process for making PRUSSIAN blue.

GREEN, *Sap*. See *colours from FRUITS*, BUCKTHORN, and SAP-green.

GREEN, *Saxon*, an extremely beautiful green colour, so called because the blue part is given by the Saxon blue or sulphat of indigo; the process of dyeing which is this; the cloth or silk is first to be dyed a Saxon blue, in the following manner. Having ground nine parts of indigo with twenty of red arsenic into a fine powder, add forty-eight parts of strong spirit of vitriol; which mixture swells, grows hot, and emits a sulphureous smell. After standing in a moderate warmth of twenty-four hours, pour off the liquid part, which will be of an extremely deep blue. A small quantity of this liquor, dropt into hot water, instantly spreads, tinges it of a fine light blue, and fits it for dyeing

the prepared wool, cloth, or silk ; and by increasing or diminishing the proportion of the blue composition, the colour may be rendered deeper or lighter. This, Dr. Lewis says, is the method used for preparing the blue composition by the dyers of Norwich, who purchased this secret from Saxony.

The cloth or silk, thus dyed blue, is next alumed, and then dipped in the yellow decoction of weld or fustic, and the desired colour will be obtained.

Fustic is commonly preferred as the yellow material, because it is less liable to be altered by the adhering acid of the sulphat of indigo than weld or the other yellows. To correct this effect of the acid, and enable quercitron to equal the fustic in this respect, (whilst its natural colour much excels it,) Dr. Bancroft advises, after the cloth has received the blue, to mix chalk with the alum mordant, in order to neutralize the adhering acid, before the yellow is given.

Or the subject may be dyed green at one operation, by boiling it for a little time in a mixture of the blue and yellow

liquors. For this purpose the cloth is first alumed and well rinsed ; and the cloth is then dyed in a strong decoction of fustic, to which, when cooled to a blood heat, is added sulphat of indigo. Dr. Bancroft recommends for dyeing a beautiful Saxon green, the following expeditious process, by using the compound alum and tin mordant ; put into the boiler six or eight pounds of quercitron bark to every one hundred pounds of cloth ; boil with a sufficient quantity of water ; then add six pounds of the murio-sulphat of tin, (in preference to the nitro-muriat,) and four pounds of alum : when these have boiled five or six minutes, lower the heat with cold water to blood-warm, after which, add as much sulphat of indigo as may be thought necessary for the intended depth of colour, and then dye the cloth in this bath with proper care. Aikin's Dict.

By combining any blue and yellow dyes, in different proportions, all the shades of green may be produced, from the blueish green of the cabbage-leaf to the greenish-yellow of the olive.

Greenock

GREENOCK, the principal sea-port town on the firth of Clyde, situated on the south bank of the river, about 24 miles below the city of Glasgow. The town of Greenock is pretty well situated for commercial purposes, but in other respects it is neither pleasant nor so circumstanced as to afford the prospect of any great increase either of extent or population. Indeed the great number of young men, who, from habits of imitation as in other sea port towns, early attach themselves to a seafaring life, must present of itself a great obstacle to the latter. The town of Greenock is held under and is entirely surrounded by the lands of sir John Stewart of Blackhall, bart., who is feudal superior, and no purchase or acquisition of ground, either for the purposes of extension or improvement, can be had from any other person. This must of itself render extension a matter of more difficulty than where there are many landed proprietors, the lands of some of whom, from the common casualties and vicissitudes of human affairs, must be occasionally in the market.

The harbour of Greenock is divided into two compartments, and is entirely surrounded by well-built and commodious quays of freestone. The entrance is narrow, and in the centre opposite to the end of the mid quay, which serves as the division of the harbours. The eastern harbour is shallow, and is therefore mostly frequented by coasting vessels, herring busses, fishing boats, and other small craft. The west harbour, being considerably deeper, is the general resort of West Indians, American traders, and other vessels of greater burthen. In the west harbour is a very capital dry or graving dock, with flood gates to exclude the water, and capable of containing two large ships at the same time. It has been long in contemplation to improve the harbour of Greenock by the erection of wet docks, similar to those of London, Liverpool, Hull, and Leith, but probably from the difficulty of engaging the joint consent of the numerous interests concerned, and other causes, no steps have been hitherto taken for carrying this scheme into effect. The principal deficiency of the harbour of Greenock, exclusive of the ships bottoms taking the ground every ebb tide, arises from want of water, there being never more than seventeen or eighteen feet in the harbour, even at spring tides. Hence large vessels are obliged to discharge part of their cargoes into lighters in the roads before they can come into the harbour at all. This is of less consequence where the cargo is to be brought to Glasgow, if the weather be mild, but it is very inconvenient and expensive when the cargo is to be landed, and when the weather is boisterous. The whole rise of the tide at Greenock is only about twelve feet, whereas at Liverpool it is thirty-six and at Bristol forty-two. This also forms an additional disadvantage to the harbour of Greenock, and

presents a very great obstacle to every plan of artificial improvement. With all these disadvantages, however, it has many advantages over the neighbouring harbour of port Glasgow, situated about three miles farther up the river. The chief obstacle to vessels of great burthen making any of these ports, is an immense bank of sand, accumulated for many ages in this *embouchure* of the Clyde by the current of the river, and which is sensibly though slowly increasing. Indeed nearly opposite to port Glasgow, this bank is entirely uncovered for miles at low water. Notwithstanding these natural disadvantages, the favourable situation of the Clyde for maritime intercourse with every part of the western hemisphere and the south of Europe, the great coasting trade with the western parts of England and Wales, and with Ireland, and the extensive herring fishery, has raised Greenock to a high rank among the commercial ports of Britain, and has been productive of the acquisition of splendid fortunes to many of the principal inhabitants. As Greenock is not the seat of any staple manufactory, this carrying trade is her chief, and indeed may be fairly called her only support. During the American war, when the carrying trade was entirely suspended in some channels, and greatly impeded in all the others, a number of ship-owners fitted out their vessels as privateers, but in general these speculations were not productive of gain to the adventurers, and in some instances with serious loss. In the recent wars no attempts at privateering have been made.

The town of Greenock is governed by two magistrates, elected annually, and a council; besides whom, the baron baillie, nominated by the superior, also possesses a jurisdiction. The sheriff court of the county of Renfrew is held at Paisley, to which the inhabitants of Greenock are amenable, the same as the rest of the county.

In the external appearance of Greenock there is little elegance or splendour to be seen. In the centre of the town there is a small square, immediately fronting the mid-quay, which divides the harbour. In this square is a very handsome church of modern architecture. The other buildings are the inns, of which the chief, recently built upon a tontine scheme, like that of Glasgow, is a very spacious, and even splendid house. There is also a small neat theatre, the private property of Mr. Stephen Kemble, the manager, and some dancing-halls for the occasional recreation of the inhabitants and strangers, of whom, from the maritime situation, there is, at certain seasons, particularly at the arrivals of the West India fleets, a considerable influx.

The scenery of the Clyde around Greenock is picturesque and sublime. The river is about seven miles broad to the opposite shore, where the village of Helensburg is erected upon the property of sir James Colquhoun of Luss, bart. This village is built in a very pleasant situation, upon a fine bay,

formed by two projecting promontories, *viz.* by the hill of Ardmore, on the east, and by Roseneath, the property, and one of the splendid residences of the duke of Argyle, on the west. Beyond this, to the westward, appear the lowering mountains of Argyleshire, between which is the vast arm of the sea, Lochlong, which is twenty-four miles in length, and in some places said to be unfathomably deep. About two miles to the west is a small village, called Gourrock, situated on a very fine deep bay, well sheltered by projecting head-lands, with a very good bottom for anchorage. It is the opinion of most professional men, whether engineers or seamen, that this situation affords by far the greatest number of natural advantages for a large and commodious sea-port upon the Clyde; and it is almost singular that Greenock should have risen to its present commercial importance, whilst Gourrock, situated within less than two miles, and possessing every superiority of physical advantage, should have remained an insignificant village. However this may have originated, too much capital has now been expended upon Greenock and Port Glasgow, to leave the smallest room to suppose that they will be in any respect rivalled by a village which possesses nothing but natural situation to recommend it. On the road from Greenock to Gourrock are many very fine villas, belonging to the opulent merchants of Greenock. At both Greenock and Gourrock are extensive rope-works, belonging to the same company of proprietors. A little below Gourrock is the Clough light-house, a very high and well-built tower, lighted by reflectors, for the safety of vessels coming up, or going down the channel during the night. Some miles below this is the island of Bute, belonging chiefly to the nobleman to whom it gives the title of marquis. Bute is about seven miles long, and generally level and fertile. Mount-stewart-castle, the residence of the noble proprietor, is situated near the middle of the island, on the south side, and is a superb and delightful place. Of the other proprietors, lord Bannatine, one of the Scottish judges, is the most conspicuous. The chief, and, indeed, almost only town on the island, is Rothsay, from which his royal highness the prince of Wales derives one of his Scottish titles, is a handsome, clean, small town, and has a considerable cotton mill and manufactory by it, belonging to a company of manufacturers in Glasgow. There are also the ruins of an old castle, which appears to have been of great extent, and once belonged to the royal family of Scotland. The inhabitants of Rothsay are chiefly sea-faring people, and employ themselves much in the her-

ring fishery during the season. Large quantities of fine cod-fish are also caught off the coasts of Bute, Arran, and Argyleshire, with which the markets of the west of Scotland are supplied, generally at a rate not exceeding two-pence *per* pound of 22½ ounces. Contiguous to Bute is a small island, called Inch Marnock, which is level and cultivated. It is the residence only of those employed in its cultivation. The island of Arran is nearly thirty miles in length, and is very mountainous. The highest hill, called Goatfield, is seen from a great distance. The island of Arran is the property of the duke of Hamilton, who is earl of Arran, who has a fine house, called Brodick castle, on the island, where his family sometimes reside, especially during the season for shooting grouse or black game. Arran used to be much noted for a smuggling trade, both in contraband articles brought by the seamen employed in the vessels trading to the Clyde, and also in the distillation of whisky. The vigilance of the revenue cruisers in the Clyde has, in a great measure, checked the former, and that of the excise officers the latter. On Arran are found a number of fine stones, and it is sometimes visited by lapidaries, during the summer, for the purpose of searching for them, or of purchasing those occasionally picked up by the natives. On the island are only two small towns or villages, *viz.* Brodick and Lamash, the latter of which, being defended from the south winds by an island in the mouth of the bay, is resorted to as a shelter in stormy weather by the ships and vessels navigating the frith of Clyde.

Besides those already mentioned, there are a few smaller islands in the frith, *viz.* the Cumbræ, which are two small islands lying pretty close to the southern shore, near the Renfrewshire coast, opposite to the village of Largs, about 16 miles below Greenock. The larger island is about two miles long, and on it is a very neat village, called Milport, chiefly inhabited by fishermen and seamen's families. The lesser island is a mere rock, where a few persons reside, who take charge of the light-house, and sometimes persons in a state of insanity are boarded here by their relatives, on account of the purity of the air, and the retirement of the situation. Farther down, and near the Ayrshire coast, is the stupendous rock, or crag of Ailfa, from which the proprietor, the earl of Cassius, derives his British title. Ailfa is a high abrupt and barren rock, totally uninhabited, and covered by myriads of sea-fowl, in search of which it is sometimes visited. Of the general trade of the Clyde notice has already been taken under the article GLASGOW.

Grind-mill

GRIND-MILL, or *Blade-mill*, in the *Manufactures*, is a kind of mill common in the neighbourhood of Sheffield, and other places where cutlery, edge-tools, and polished steel articles, as fenders, &c. are manufactured: in these mills, a great number of large grind-stones are mounted on spindles, and, by means of traps, are turned with great velocity. Water, in all the rivers and brooks near Sheffield, was formerly applied to these mills, but of late years several large steam-engines have been applied, to work additional grind-mills in the town and neighbourhood: the first of which was erected by the late Mr. Francis Thompson, engineer, of Ashover, Derbyshire. See **CUTLERY**.

GRIND-STONE, *cos gyralis*, in *Natural History*, is a very coarse, rugged, rough, and harsh stone, of a yellowish brown colour, composed of an irregular grit, cemented together by a coarse and debased terrene crystalline matter, and intermixed with a very few glittering spangles of white talc; it cuts freely, but bears no polish; it is pervaded by water, will not strike fire with steel, is not acted upon by acids, and burns to a deep red colour, but acquires no hardness. It is chiefly dug in the northern counties of England, and used for grind-stones, whence its name.

GRIND-STONES, in the *Manufactures*, are flat circular stones used for the grinding of edge tools, when such are mounted on a spindle, and turned by a winch-handle, as is common in every part of the country; but in districts where cutlery and tools are manufactured, great numbers of these stones are used in one building, called a grind-mill or blade-mill, and are turned by water or steam-engines. (See **GRIND-MILL**.) The stone suited to form grind-stones is what is denominated a sharp grit, that is, the grains of sand or flint of which it is composed are partly uniform in size, and are firmly attached to each other by a silicious or other very hard cement, without the interstices between the grains being filled up, as frequently is the case, or nearly so, with the other kinds of sand-stone. Grind-stones are of very different degrees of fineness, in the grains of flint, according to the different strata whence they are obtained: the coarsest and best for heavy works, such as the grinding of gun-barrels, &c. are from the first or mill-stone grit of the Derbyshire strata (see the section of these, in the *Phil. Mag.* plate 2, vol. xxxi.): others are from the third rock, the next stratum but two above the former: and in other counties coarse grind-stones are manufactured from the coarse grit rocks near the bottom of their different coal series; for it is rather remarkable, that all the grind-stone quarries with which we are acquainted, are in the coal-measures or strata where vegetable remains abound. The finer sorts of grind-stones, and what are called whitening or polishing stones by the

Sheffield cutlers, are from *different* rocks, in the upper part of the great Derbyshire coal-series; Mr. Whitehurst, p. 168. of his "Inquiry," seems to have known, or distinguished but two out of the 18 or 20 grit-stone rocks which this series contains, and says, "the upper stratum of argillaceous stone is excellent for the use of cutlers' grinding-stones." Mr. Mawe's knowledge of these strata seems to have been equally confined, see his section and description in the "Mineralogy of Derbyshire," p. 14. It may prove interesting to many of our readers, to see the following list of grind-stone quarries, with their degrees of coarseness, viz.

Ashover, N.W. (hill quarry) Derbyshire, middling.
 Ayrethire (water of Ayre) Scotland.
 Beely Moor, E. of the town, Derbyshire, coarse.
 Belper, S.E. (Hungerhill) Derbyshire, middling.
 Biddulph-Hall, N.W. of Leek, Staffordshire, coarse.
 Bilstone, S.E. of Wolverhampton, Staffordshire, middling.
 Bolsover, N.W. (nunnery) Derbyshire, middling.
 Bredfal Moor, N. of Derby, middling.
 Briucrif-edge, S.E. of Sheffield, Yorkshire, fine.
 Buxton, N. (Corbar) Derbyshire, fine.
 Darley Moor, E. of the town, Derbyshire, coarse.
 Gate-head fell, S. of Newcastle, Durham.
 Glossop, Derbyshire, coarse.
 Harthill, S.E. Yorkshire, fine.
 Hooton-Roberts, near Rotherham, York, middling.
 Horsley, N. of Derby, fine.
 Lane-top, N. of Sheffield. Yorkshire, whitening.
 Little-Eaton, N. of Derby, coarse.
 Milford, S. of Belper, Derbyshire, coarse.
 Molecote-hill, S. of Congleton, Cheshire, coarse.
 Morley-Moor, N. of Derby, fine.
 Norton, W. (Hemp-yard lane) Derbyshire, fine.
 Overton (Gregory) in Ashover, Derbyshire, coarse.
 Poleworth, S.E. of Tamworth, Warwick.
 Purton, W. of Wolverhampton, Staffordshire, fine.
 Ridgeway (Lum-delph) in Eckington, Derbyshire, fine.
 Stanley, N.E. of Derby, fine.
 Stanton by Dale, E. of Derbyshire, fine.
 Stanton Moor, N.E. of Winstar, Derbyshire, coarse.
 Therberg, near Rotherham, Yorkshire, fine.
 Treton ditto. ditto. fine.
 Warton, E. of Tamworth, Warwickshire.
 Wickersley, near Rotherham, Yorkshire, middling.
 Wokes, near Barnsley, Yorkshire.

Some of these quarries are very ancient; that in Ashover is noticed in the Domesday survey, but since the inclosure of the parish it has been disused. The sale of grind-stones

from some of them, where navigations are near, are very considerable.

GRINDERS, MOLARES *dentes*. See *Molares* under the article **CRANIUM**.

GRINDING, TRITURATION, the act of breaking or comminuting a solid body, and reducing it into powder, dust, flour, farina, or the like.

Grinding is one of the species of dissolution. The painters' colours are ground on a marble or porphyry, either with oil or gum-water.

Some late physicians contend, that digestion is performed by grinding the food in the stomach. See **DIGESTION**.

GRINDING is also used for rubbing or wearing off the irregular or otherwise redundant parts of the surface of a body, and reducing it to the destined figure, whether that be flat, concave, or the like.

The *grinding of glasses* is a considerable art, and, as such, necessarily requires to be here insisted on; especially that of optic glasses.

Method of grinding optic-glasses.—For convex glasses, the first object is to provide a dish or bason, within whose cavity the glass is to be formed.

In order to this, they take a piece of brass, copper, iron, or wood, and form it into a segment of a circle, having the radius of the bason or the dish intended: this done, a bason is forged by a smith, either of iron or copper, having its cavity exactly fitting or corresponding to the segment above mentioned, though sometimes they chuse to have the bason cast; in this case, the rules elsewhere delivered for concave mirrors are to be here observed. (See **MIRROR**.) The figure of the bason, thus roughly formed, is to be finished in the pewterer's lathe, or on a stone mould A, *Plate V. Optics*, *fig. 3*, fixed to an iron axis with a pinion B C, moveable by a wheel D E, and that by a winch or handle F. The bason being ground on the mould till it exactly fits in all parts, they take it off, and cementing it to a wooden block (loaden, if need be, with lead), strew it over with fine sifted sand, and thus grind it over again on the mould, till all the furrows or scratches be quite taken away.

Lastly, they grind large pieces of glass in a bason, with fine sand between, till such time as, its surface being well smoothed, there is no longer any opposition to the motion.

Note, the dish is known to be perfectly finished when, a hair being stretched over it, its shadow projected in the cavity, especially in a camera obscura, does not appear any way distorted.

The bason finished, they proceed to choose glasses for the purpose: in order to this, lay them on clean paper, and observe what colours are projected upon it; for the same are the colours of the glasses. Always set aside those of the darker colours, and choose the brighter; but as the whitest and brightest have usually veins, and besides, in tract of time, by the humidity of the air, are apt to rust and lose their polish; for this reason Huygens recommends those a little yellowish, reddish, or greenish; Hevelius the blueish. A glass is found to be free from bubbles, sands, veins, knots, and spires, by holding it to the sun, and receiving the rays through it on a white paper; for the flaws above mentioned will each project a shadow upon it.

If, instead of lenticular, or at least spherical glasses, you make use of plate-glass, it must be divided and cut with a diamond into squares; and if it be too thick to break otherwise, you may do it by laying it on a table covered with cloth, in such manner as that the side or part to be severed hang over the edge: for, being struck with an iron

instrument, in this situation, it easily breaks in the direction of the line drawn by the diamond. Having thus got a square piece, describe two concentric circles upon it with a pair of compasses, one of whose legs carries a diamond: the diameter of the inner circle to be equal to the breadth of the intended lens, and that of the outer somewhat more; and break off the corners, as above directed, and the lesser inequalities take off on a grind-stone, or the like. Examine now whether the piece of glass be every where equally thick; if it be not, reduce it to such equality by grinding it on an iron plate with sand and water. Lastly, glue or cement the glass thus prepared to a wooden handle N M O, *fig. 4*, with a cement made of pitch and a fourth part of resin, or one part of wax and eleven of colophony: care being taken that the base or bottom of the handle N O be equal to the glass, and that the centre of the glass and handle meet together. Smaller lenses, as those used for microscopes, are fixed on with sealing-wax.

Now, to grind the glass, and bring it to the convexity required, smear over the dish equally with fine sifted sand moistened with water; then taking the handle with the glass on it, work it on the bason, sometimes this way, and sometimes that, to prevent the form of the bason from being disturbed, never leaning too hard upon it. When the glass has got the figure of the bason, clean it well of all the sand and filth adhering, and sprinkle the bason over with emery moistened in water, grinding the glass thereon till all the roughness and inequalities are taken away: after this, the fine sand used in hour-glasses may be of service, applied and used as before; remembering to take out the sand, when too much worn, and substitute new in its stead. Some, in lieu of this, choose several sorts of emery, each finer than the other, or even the power of flint calcined and pounded. Lastly, grind the same glass in another bason or dish, which is a segment of a lesser sphere, making use of the like sand as before, till it has got a pretty high rim or margin all around. Because the pressure is not here determined accurately enough upon the middle of the glass, by the mere guidance of the hand, some have chosen to make use of the following machine, especially for grinding object-glasses.

Fix the dish H I, *fig. 5*, on a horizontal table; exactly over its centre let the aperture D be, through which pass an iron arm five or six inches long, fastened to the staff A B: let the other extreme of the staff be fitted into a hole cut in the dish, and fastened therein. Now to grind the glass instead of the dish, take hold of the said staff, and work with sand, &c. as before.

Huygens tells us, that he always used first a coarse emery, then a finer powder of the same, which would be fifty seconds in sinking to the bottom of a vessel of water, putting in fresh every half or quarter of an hour: sometimes too, he used emery of fifty seconds, for three quarters of an hour; then emery of four hundred seconds, for four-fifths of an hour; and lastly, emery of forty-five minutes, for a quarter of an hour. The same effect is had from powder of flints, broken in an iron mortar, mixed with water, and stirred sometimes with a wooden spatula, taking the powder as it precipitates in some certain time to the bottom of the vessel, by decanting the water. What remains is to polish the glass.

For a more particular account of the method of grinding and polishing glasses for telescopes, extracted from Mr. Huygens and other authors, by Mr. Molyneux, and comprehending the method of making and polishing the tools, of choosing the glass, of preparing the glasses before they can be ground and polished, of grinding the glasses, and of

giving them the last and finest polish, we must refer to Smith's *Optics*, book iii. chap. i. *passim*.

The late ingenious Mr. James Short, in a paper left with the Royal Society, to be opened and printed after his death, gives the following directions for working object-glasses of refracting telescopes truly spherical.

Prepare two plates or tools, of brass, the one convex, and the other concave, being both portions of a sphere of the same radius as the focal length of the object-glass you want to have, or rather of a radius somewhat longer than the focal length you want, for a dioptrical reason; let these plates or tools be between two and three times the breadth of the object-glass desired; or, in long focal lengths, twice the breadth will be sufficient: let these tools be of a sufficient thickness in proportion to their breadth or diameter, and let them be ground with fine emery exactly true to one another, working them alternately, the one above the other, to preserve the same focal length; or, if it is desired longer, you must work the convex above the concave; or, if desired shorter, you must grind the concave above the convex.

After this, you prepare another brass plate or tool, of the same breadth and thickness as the two former, and of the same radius of concavity: its being truly turned on a lathe will be sufficient for this purpose; which tool is to serve afterwards for the polishing of the two surfaces of your object-glass, and therefore called the polishing tool.

Prepare a piece of straw-coloured glass, of the plate-glass kind, of the proper diameter for the object-glass you desire, which ought always to be broader than the proper aperture for that length; let this piece of glass be ground flat, in another tool, on both sides and as nearly parallel as may be, and somewhat polished, in order to discover whether there are any veins or flaws in the glass. When you are satisfied of the goodness of the glass, you are then to prepare a handle to fasten your glass to. Great care must be taken in this, for fear of bending your glass by the handle: Mr. Short advises to take a flat piece of brass, or rather of the concavity of the sphere, to which the glass is to be ground; this piece of brass should not be thicker than two-thirds of the thickness of the glass, of a circular form, less in breadth somewhat than the glass itself, and having sides of the same form, at right angles to the flat piece of brass, and these sides ought to be of such a shape as that the fingers may easily apply to it in working, and these sides should be as low as may conveniently be, and no thicker than about two-thirds of the glass. This handle is to be fastened to the glass, by warming the glass and handle gently before a fire, and laying some pitch upon the glass thus warmed, till it becomes soft like melted wax; and then laying your brass handle, a little heated, on the pitch, you press it a little, till you are sure there is nothing between the glass and the handle but pitch; you then lay down the glass and handle upon something flat, taking care that the handle is in the middle of the glass till it is entirely cold. It is very material to know, that the pitch, to be used for fastening the handle to the glass, must be soft pitch, that has never been used nor melted; for any other pitch will infallibly bend the glass.

You then grind your glass in the concave tool with emery, and give it the proper figure and smoothing for the last polish, in the common manner.

In order to give your glass the last polish, which is the most difficult part of the whole work, you are to prepare some pitch for covering the before-mentioned polishing concave tool, which is done in this manner: take some pitch, and melt it in an iron ladle, and let it boil for a quarter of an hour or thereabouts; by this boiling, the pitch, when cold, will become hard and

brittle: or you may shorten this operation, by melting equal quantities of pitch and rosin, and then there is no occasion to let it boil so long. Your pitch being thus prepared, you again melt it, and take it off the fire, and let it stand till the pitch becomes pretty cold, or of a thickish consistence; and having warmed the polishing tool a little, to make the pitch stick to it, you pour out of the ladle upon the polishing tool as much pitch as you judge will cover the whole tool, when spread out, to about the thickness of one-eighth of an inch; you then invert this tool with the pitch upon it, and press it upon the convex tool, which must be quite dry, clean, and cold, in order to give it the figure of the convex tool: in case it has not spread out so as to cover the whole surface of the polishing tool, you may warm the pitch by holding it before the fire, and pressing it upon the convex tool, as before, till it has entirely covered the surface of the polishing tool; you then plunge it into cold water, till the brass is quite cold.

N. B. In order to know if your pitch is hard enough, you press the edge of the nail of your thumb upon it, and if it receives an impression, the pitch is not hard enough.

You then proceed to prepare this polishing tool, for the last polish of your glass, by grinding this polishing tool upon the convex tool with pretty coarse emery, and a small quantity of water, in the common way that tools are ground one upon another; but this must be done only for a small space of time, and the polishing tool must have no other pressure than its own weight, for fear of some of the emery sticking in the pitch, and you must never allow the emery to grow dry: when you have ground the pitch, so as to be all over of the same colour, you then wash the pitch from all the emery with a brush and clean water; after this, you take a bottle of water, and, holding the pitch tool in a sloping position, you pour water out of the bottle so as to fall upon every part of its surface.

You then place the polishing tool in a horizontal position, and you put upon it some putty, washed from all its gritty particles, but it need not be the finest washed, and you put a good deal of water upon your polishing tool, mixing the putty and it together, and you polish your glass upon this pitch-polisher in the common manner of polishing glasses.

After you have polished your glass about ten minutes, you again grind your polisher upon the convex tool with emery, as before, for fear the pitch has, by working, lost any of its proper figure; and the oftener you do this, the truer will be the figures of your glass; and in this manner you proceed till the glass is quite polished.

You then take your glass off its handle, by holding it before the fire, till it is so warm that you can slide the handle off the glass; and whilst the glass is warm, you take off as much of the pitch as you can with the sharp edge of a knife; you then lay the glass down to cool, and when quite cold, you drop some spirits of wine upon it; and this, with a cloth, will wipe off the rest of the pitch.

You then examine the centre of the surfaces of your glass; and if it lies to one side of the centre of your glass, mark that place with a spot of ink, and then put on your handle as before, upon the side that is now polished, with its centre over the spot of ink, and grind your glass as before, till the circular remaining part of the glass to be ground is as much distant from the centre of the glass on the other side from the spot as the spot was from the centre of your glass; you then, by heat, return your handle to the centre of the glass, and proceed to grind and polish this side of the glass as before.

N. B. The concave and convex tools should be ground with fine emery, after you have done one side of your glass;

for the oftener these are ground together, you will be the more sure of having your figure true. Phil. Transf. vol. lviii. p. 507, &c.

Method of Grinding, &c. the specula of reflecting telescopes.
—The method generally followed by workmen is that proposed by Messrs. Molyneux and Hadley, and published in Dr. Smith's Optics; this has been lately improved, in a very considerable degree, by Mr. Mudge, whose directions, founded on accurate experiments, and practised with success in the construction of telescopes, we shall adopt wherever they differ from those that occur in the book just cited. For making the gages, take a long pole of fir, deal, or any wood, of a little more than double the length of the instrument intended, and strike through each end of it two small steel points, and by one of them hang it up perpendicularly against a wall; then take two pieces of thin plate-brass, well hammered, a little thicker than a sixpence, which may be about an inch and a half broad, and let their length be in proportion to the diameter of the speculum as three to two; so that if the speculum be eight inches diameter, these may be about twelve. Fix each of these strongly with rivets between two thin pieces of wainscot, so that a little more than a quarter of an inch in the breadth may stand out from between the boards. Then fix up these pieces horizontally against the wall under your pole, and therewith, as with a beam-compass, strike an arch upon each of them; then file each of them with a smooth file to the arch struck, so as one may be a convex and the other a concave arch of the same circle. These brasses are the gages to keep the speculum, and the tools on which it is ground, always to the same sphere: and that they may be, therefore, perfectly true to each other, it is necessary to grind them with fine emery one against the other, laying them on a flat table for that purpose, and fixing one of them to the table. When the gages are perfectly true, let a piece of wood be turned about two-tenths of an inch broader than the intended speculum, which it is best to cast in no case less than two-tenths of an inch thick; and for specula of six, eight, or ten inches broad, this should be at least three or four-tenths thick when finished. This board being turned, take some common pewter, and mix with it about one-tenth of regulus of antimony, and with that wooden pattern, cast one of this pewter, which will be considerably harder than common pewter. Let this pewter pattern be truly turned in a lathe, and examined by means of the gages before-mentioned, as a pattern for casting the specula themselves; and take care, when it is turned, that it be at least one-twentieth of an inch thicker, and about one-tenth of an inch broader than the speculum intended to be cast from it. The manner of making the moulds for casting is now to be explained, and will serve for a direction as well for casting this pewter pattern, as afterwards for casting thereby the speculum itself. The flasks should be of iron, and at least two inches wider every way than the speculum intended. In each flask there should be the thickness at least of one inch of sand. The casting-sand which the common founders use will answer the purpose as well as any; and any sand will do which is naturally mixed with a small proportion of clay, to make it stick. The sand should be as little wet as may be, and well beaten, but not too hard. The ingates should be cut so as to let the metal flow in, in four or five streams, over the whole upper part of the mould; otherwise, whatever pores happen in the metal will not be so equally dispersed as they should be over the whole face of the metal, these pores generally falling near the ingate streams. Let the flasks dry in the sun for some hours, or near a very gentle fire, otherwise they will warp, and give the speculum, when cast, a

wrong-figure: for, besides saving the trouble in grinding, it is best, on many accounts, to have the speculum cast of a true figure; and for this reason it is best to cast it from a hard pewter pattern, and not from a wooden one, as founders usually cast.

For the composition of the metal and manner of casting it, see SPECULUM. When the metal is cast, the next business is to grind and polish it, for which, says Mr. Mudge, four tools are all that are necessary, viz. 1. The rough-grinder, for working all the rough face of the metal: this is best made of lead, stiffened with about a fifth or sixth part of tin; it should be at least a third more in diameter than the metal which is to be ground; and for one of any size, not less than an inch thick. It may be cemented on a block of wood, in order to raise it higher from the bench.

This leaden tool being cast, must be fixed in the lathe, and turned as true as possible by the gage to the figure of the intended speculum, making a hole in the middle, as a lodgment for the emery, of about an inch diameter, for a metal of four inches; when this is done, deep grooves must be cut across its surface with a graver, in the manner represented in *Plate V. Optics, fig. 6*; these grooves will serve to lodge the emery, and by their means the tool will cut much faster. Any kind of low handle, fixed on the back of the metal with soft cement, will be sufficient; but it should cover two-thirds of its back, to prevent its bending.

2. The next tool is the convex brass-grinder, on which the metal is to receive its spherical figure. In order to form this tool, procure a round stout piece of Hamburg brass, at most a sixth part larger than the metal to be polished; and let it be well hammered into a degree of convexity, by the assistance of the gage, suitable to the intended speculum: then scrape and clean the concave side so thoroughly, that it may be well tinned all over; then cast upon it, after it has been pressed a proper depth into the sand, the former composition of tin and lead in such a quantity, that it may, for a speculum of four inches diameter, be at least an inch and a half thick, and with a base considerably broader than the top, in order that they may stand firmly upon the bench in the manner hereafter to be described. This being done, it must be fixed and turned in the lathe with great care, and of such a convexity as exactly to suit the concave gage. This tool must have a hole, somewhat less than that in the metal to be worked upon it, in the middle, quite through to the bottom. When it is finished off in the lathe, its diameter should be one-eighth wider than the metal.

The 3d tool is the bed of hones, the use of which is to perfect the spherical figure, and to give the metal a fine smooth face. See *Bed of HONES*.

The 4th and last tool is the bruiser, with which both the brass-grinder and the hones are to be formed; this tool should be made of thick stout brass, perfectly sound, about a quarter of an inch thick, and hammered as near to the gage as possible; it should be then scraped, cleaned, and tinned on the convex side, as the second tool was on the concave, and the same thickness of lead and tin cast upon it. This should be as broad at bottom as at top; and when it is fixed in the lathe, and turned off concave to the convex gage with accuracy, the diameter ought to be of a middle size between the hones and the polisher or brass grinder, which is used for this purpose. Having with the lathe roughly formed the convex brass grinder, the bed of hones, and the concave bruiser, the convex and concave brass tools and the metal must be wrought alternately and reciprocally upon each other with fine emery and water, so as to keep them to the same figure as nearly as possible, in order to which some washed emery must be procured, by putting it into a bottle,

Half filling the bottle with water, and shaking the mixture; so that the coarsest of the emery will subside to the bottom first, and the finest remain at the top: when fresh emery is laid on the tools, it is best done by gently shaking the bottle, and pouring out a small quantity of the turbid mixture. The next operation is to grind the brass convex tool with the bruiser upon it, which is continued for about a quarter of an hour, and then the convex tool is wrought upon the bruiser in the same manner. When these have been wrought on each other, occasionally adding fresh emery, till the vestiges of the turning tool are got out and both brought nearly to a figure, the same form must be given to the metal, by grinding it upon the brass tool with the same kind of emery; taking care, however, by working the two former tools frequently together, to keep all three exactly in the same curve. The best kind of handle for the metal is made of lead, a little more than double its thickness, and somewhat less in diameter, of about three pounds weight, with a hole in the middle, a little larger than that in the metal: the handle should be cemented on with pitch. The upper edge of this weight must be rounded off, that the fingers may not be hurt, and a groove, about the size of the little finger, be turned round just below it, for the more conveniently holding and taking the metal off the tools. When the bruiser, brass tool, and metal, are all brought to the same figure, and have a good surface, the next part of the process is to give a correct spherical figure and a fine face to the metal, upon the hones; these, however, should be covered with water for at least an hour before they are used, otherwise they will be liable to alter their figure; and they must be never suffered to grow dry whilst they are in use, for the same reason.

In order to give a proper figure to the hones, corresponding to that of the brass tool, bruiser, and metal, when they are fixed down to the block, some common flour emery, unwashed, with a good deal of water must be put upon them, and the bruiser being placed upon the hones, and rubbed over them with a few strokes and a light hand, the inequalities of the stone will be soon worn off, the mud that is generated being washed away, every quarter of a minute, with a great deal of water. As soon as the hones have received the general figure of the bruiser, and all the turning strokes are worn out from them, the emery must be carefully washed off, and cleared from the joints with a brush under a stream of water. The bruiser and metal must be likewise cleared in the same manner. The hones being fixed down to the block, the bruiser must be worked upon them with very cautious, regular, short strokes, forward and backward, to the right and left, turning the axis of the bruiser in the hand while you move round the hones, by shifting your position, and walking round the block. The manner of conducting this operation is minutely described by Mr. Mudge. The metal may then be rubbed upon the hones in the same cautious manner, occasionally rubbing the bruiser upon the hones, in order to sharpen them. When in this way the hone pavement has given a fine face and true figure to the metal, you may proceed to try the metal as judge of its figure, by washing the hone-pavement quite clean; then putting the metal upon the centre of it, and giving two or three light strokes round and round only, without carrying the edges of the metal much over the hones; this will take out the order of straight strokes; then having again washed the hones and placed the speculum upon their centre, with gentle pressure, slide it towards you till its edge be brought a little over that of the hones; then carry it quite across the diameter as far as the other side, and having given the metal a light stroke or two in this

direction, take it off the tool. The metal being wiped quite dry, place it upon a table at a little distance from a window; stand as near the window, at some distance from the metal, and looking obliquely on its surface, turn it round its axis, and you will see at every half turn the grain given by the last cross strokes flash upon your eye at once over the whole face of the metal. This is a certain proof of a true spherical figure.

The last operation is that of polishing the speculum, and this is the most difficult and essential part of the whole process. Mr. Mudge, having made some strictures on the method of Messrs. Hadley and Molyneux, generally followed, describes at large that which he has discovered after a number of trials, both of giving a correct parabolic figure and an exquisite polish at the same time. Availing himself of the manner of polishing with pitch practised by Sir Isaac Newton, and mentioned in his *Optics*, he formed his polisher by coating the brass convex tool equally with pitch, which should be neither very hard and resinous nor too soft, about the thickness of a shilling, and by applying the bruiser to it, gave the pitch upon the polisher a fine surface and the true form of the bruiser. He then divided the leaden weight upon the back of the metal into eight parts, by strokes on the surface of the lead, which are marked with the numbers 1, 2, 3, 4, &c. in order to distinguish and regulate the turns of the metal. He also put half an ounce of putty into an ounce phial, and filled it two-thirds with water; and having shaken the whole, let the putty subside, and stopped the bottle with a cork: the other appendages of his apparatus are a small-sized camel's hair brush in a tea-cup with a little water, a piece of dry clean soap in a gally-pot, and a soft piece of sponge. These, as well as the metal, bruiser, and polisher, should be constantly covered from dust.

The polisher being fixed down, is brushed over with the camel's hair brush, after it has been wetted and rubbed a little over the soap; then the bruiser is worked lightly upon it, till it has acquired a good face and is fit for the metal. Then, having shaken up the putty in the phial, and touched the polisher in five or six places with the cork wetted with that and the water, the bruiser is placed upon the tool, and a few strokes given to it upon the putty, in order to rub down any gritty particles: after which, having removed it, the metal is worked lightly upon the polisher round and round, carrying the edges of the speculum, however, not quite half an inch over the edge of the tool, and now and then with a cross stroke. The putty is repeatedly applied in the same manner, and wrought into the pitch in the course of the operation; and if the bruiser be apt to flick, and does not slide smoothly on the pitch, the surface of either tool may be occasionally brushed over with the soap and water. After some continuance of this process, the pitch is well defended by the coating of the putty, and the metal, pressed only by its own weight and that of the handle, and occasionally softened, moves over it with a more uniform and regular friction. When the polish of the metal nearly reaches the edge, the round strokes must be gradually altered for the short and straight ones. When this has been done for some time, in the manner minutely described by Mr. Mudge, the metal will begin to move stiffly as the friction increases, and the speculum polishes very beautifully and speedily, and the whole surface of the polishing tool will be equally covered over with a fine metallic bronze. As the metal wears much, its surface must be now and then cleaned with a piece of shammy leather, and the polisher likewise with a soft piece of wet sponge. You will now be able to

judge of the perfect spherical figure of the metal and tool, when there is a perfect correspondence between the surfaces, by the fine equable feel there is in working, which is totally free from all jerks and inequalities. Having proceeded thus far, you may put the last finishing to this figure of the metal by bold cross strokes, only three or four in the direction of each of the eight diameters, turning the metal at the same time: this must be done quickly; for, if the tool be suffered to grow quite dry, you will never be able, with all your force, to separate that and the metal, without destroying the polisher by heat. The metal will now have a beautiful polish, and a true spherical figure, but will by no means make a sharp distinct image in the telescope; for the speculum will not be found to make parallel rays converge without great aberration: and, indeed, the deviation will be so great, as to be very sensibly perceived by a great indistinctness in the image.

Supposing then the metal to be now truly spherical, stop the hole in the polisher, by forcing a cork into it underneath, about an inch, so that it do not reach quite to the surface; and having washed off any mud that may be on the surface of the tool with a wet soft piece of sponge, whilst the surface of it is a little moist, place the centre of the metal upon the middle of the polisher; then having, with the wet brush, lodged as much water round the edge of the metal as the projecting edge will hold, fill the whole of the metal and its handle with water, to prevent the evaporation of the moisture, and the consequent adhesion between the speculum and polisher, and let the whole rest in this state for two or three hours: this will produce an intimate contact between the two, and by parting with any degree of warmth they may have acquired by the nearness of the operator, they will become perfectly cold together. By this time you may push out the cork from the polisher to discharge the water, and give the metal the parabolic figure, in the following manner: move the metal gently and slowly at first, a very little round the centre of the polisher, then increasing by degrees the diameter of these strokes, and turning the metal frequently round its axis, give it a larger circular motion, without any pressure, but its own weight: this manner of working may safely be continued about two minutes, moving yourself, as usual, round the block, and carrying the round strokes, in their increased and largest state, not more than will move the edge of the metal half an inch or five eighths over the tool. The speculum must not all this while be taken off from the polisher, and consequently no fresh putty can be added. It will not be safe to continue this motion longer than the time above-mentioned; for if the parabolic tendency be carried in the least too far, it will be impossible to recover a true figure of that kind, but by going through the whole process for the spherical one in the manner before described, by the cross-strokes upon the polisher, which takes a great deal of time.

In order to try the true figure of the speculum, place it in the telescope for which it is intended, and use the instrument as a kind of microscope, moving the object to such a distance that the rays may be nearly parallel. At about twenty yards a watch-paper, or some such object, on which there are some very fine hair-strokes of a graver, is fixed up. The lead must be taken off from the speculum, the speculum placed on the cell of the tube, and the instrument directed to the object; make an annular kind of diaphragm with card-paper, so as to cover a circular portion of the middle part of the metal between the hole and the circumference, equal in breadth to about an eighth part of the diameter of the speculum; this paper ring should be fixed in the mouth of the telescope, and remain so during the whole experiment, for the part of the metal covered by it is supposed to be perfect, and therefore unemployed.

There must likewise be two other circular pieces of card-paper cut out, of such sizes, that one may cover the centre of the metal by completely filling the hole in the last described annular piece; and the other, such a round piece as shall exactly fit into the tube, and so broad, as that the inner edge may just touch the outward circumference of the middle annular piece. It would be convenient to have these two last pieces so fixed to an axis, that they may be put in their places or removed from thence so easily as not to displace or shake the instrument. All these pieces therefore together will completely shut up the mouth of the telescope.

Let the round piece which covers the centre of the metal, or that which has no hole in it, be removed; and, by a nice adjustment of the screw, let the image (which is now formed by the centre of the mirror) be made as sharp and distinct as possible. This being done, every thing else remaining at rest, replace the central piece, and remove the outside annular one, by which means the circumference only of the speculum will be exposed, and the image now formed will be from the rays reflected from the outside of the metal. If there be no occasion to move the screw and little metal, and the two images formed by these two portions of the metal be perfectly sharp and equally distinct, the speculum is perfect, and of the true parabolic curve; or at least the errors of the great and little speculum, if there be any, are corrected by each other.

If, on the contrary, under the last circumstances, the image from the outside of the metal should not be distinct, and it should become necessary, in order to make it so, that the little speculum be brought nearer, it is plain that the metal is not yet brought to the parabolic figure; but if, on the other hand, in order to procure distinctness, you be obliged to move the little speculum farther off, then the figure of the great speculum has been carried beyond the parabolic, and hath assumed an hyperbolic form. When the latter is the case, the circular figure of the metal must be recovered (after having fixed on the handle with soft pitch) by bold cross strokes upon the polisher, finishing it again in the manner above described. If the speculum be not yet brought to the parabolic form, it must cautiously have a few more round strokes upon the polisher: indeed a very few of them, in the manner before described, make in effect a greater difference in the speculum than would be at first imagined. If a metal of a true spherical figure were to be tried in the above-mentioned manner in the telescope (which Mr. Mudge has frequently done), the difference of the foci of the two segments of the metal would be so considerable, as to require two or three turns of the screw to adjust them; so very great is the aberration of the spherical figure of the speculum, and so improper to procure that sharpness and precision so necessary to a good reflecting telescope.

Supposing that the two foci of the different parts of the metal perfectly coincide, and that by the union of them, when the apertures are removed, the telescope shews the objects very sharp and distinct, you are not however then to conclude that the instrument is not capable of farther improvement; for you will perceive a sensible difference in the sharpness of the image, under different positions of the great speculum with respect to the little one, by turning round the great metal in its cell, and opposing different parts of it to different parts of the little metal, correcting by this means the error of one by the other. This attempt should be persevered in for some time, turning round the great speculum about one-sixteenth at a time, and carefully observing the most distinct situation each time the eye-piece is screwed on: when, by trying and turning the great metal all round,

the distinct position is discovered, the upper part of the metal should be marked with a black stroke, in order that it may always be lodged in the cell in the same position. This is the method Mr. Short always used; and the caution is of so much consequence, that he thought it necessary to mention it very particularly in his printed directions for the use of the instrument.

And farther, Mr. Short frequently corrected the errors of the great by the little metal in another way. If the great speculum did not answer quite well in the telescope, he cured that defect, sometimes by trying the effect of several metals successively, by this means correcting the errors of one by the other.

The apparatus above-described, for examining the parabolic figure of the speculum, is represented in *Plate V. Optics, fig. 7*: A A is the mouth of the telescope, or edge of the great tube; B B is a thin piece of wood fastened into and flush with the end of the tube, to which is permanently fixed the annular piece of pasteboard *c c*, intended to cover and to prevent the action of the corresponding part of the speculum. D is another piece of pasteboard, fixed by a pin to the piece of wood B B, on which it turns as on a centre; so that the great annular opening H H may be shut up by the ring F F, or the aperture G G by the imperforate piece E, in such manner that, in the first instance, the reflection may be from the centre, and in the latter, from the circumference of the great speculum.

Mr. Mudge has remarked, that the operation of polishing will not proceed well in the heat of summer or the cold of winter; and that neither this, nor the other of grinding upon the hones, will go on so well, unless they be continued uninterruptedly from beginning to end. In the above account it has been supposed, that the metal to be wrought was about four inches diameter; if it be either larger or smaller, the sizes of the hones, bruiser, and polisher, must be proportionably different.

The process for polishing the little speculum of a telescope must be conducted in the manner already described, for that of the large one; only observing, that as the little metal has an uninterrupted face, without a hole, so there is no occasion for one in the polisher; and likewise that, as the spherical figure is the only object in this case to be attempted, the difficulty of execution is much less than in the former. As it is always necessary to solder to the back of the little speculum a piece of brass, as a fixture for the screw to adjust its axis; Mr. Mudge has communicated a neat and safe method of doing it, which he received from the late Mr. Jackson, and which may be very useful to the optical or mathematical instrument-maker upon other occasions. Having cleaned the parts to be soldered very well, cut out a piece of tin-foil the exact size of them; then dip a feather into a pretty strong solution of sal ammoniac in water, and rub it over the surfaces to be soldered; after which place the tin-foil between them as fast as you can (for the air will quickly corrode their surfaces so as to prevent the solder taking), and give the whole a gradual and sufficient heat to melt the tin. If the joints to be soldered have been made very flat, they

will not be thicker than a hair: though the surfaces be ever so extensive, the soldering may be conducted in the same manner, only that care must be taken, by general pressure, to keep them close together. In this manner, for instance, a silver graduated plate may be soldered on to the brass limb of a quadrant, so as not to be discernible by any thing but the different colour of the metals.

We shall close this article with observing, that a method of giving the parabolic figure to his great speculum was a point of perfection which Gregory and Newton had wished for, but despaired of attaining, and which Hadley does not appear to have attempted either in his Newtonian or Gregorian telescope. Mr. Short is said to have possessed the secret; however, it died with that ingenious artist. The method discovered by Mr. Mudge, above recited, is, as he has strong reason to believe, the same with that of Mr. Short. See farther on this subject Smith's *Optics*, book iii. chap. ii. and Mr. Mudge's excellent paper in the *Phil. Trans.* vol. lxxvii. part i. art. 16. p. 296—348. See TELESCOPE.

GRINDING is also used for a coarser and less accurate method of smoothing or polishing the surface of a body, particularly glass for looking-glasses, &c.

In the new method of working large plates of glass for looking-glasses, coach-glasses, &c. by moulding, and, as it were, casting them, somewhat after the manner of metals, described under the article GLASS, the surface being left uneven, it remains to be ground and polished. In order to this, the plate of glass is laid horizontally on a stone in manner of a table, and to secure it the better, plastered down with mortar or stucco, that the effort of the workman, or of the machine used therein, may not shake or displace it; to sustain it, there is a strong wooden frame that surrounds it an inch or two higher than the glass: the bottom or base of the grinding engine is another rough glass about half the dimensions of the former; on this is a wooden plank, cemented to it; and upon this are proper weights applied, to promote the triture, the plank or table being fastened to a wheel, which gives it motion. This wheel, which is at least five or six inches diameter, is made of a very hard but light wood, and is wrought by two workmen placed against each other, who push and pull it alternately; and sometimes, when the work requires it, they turn it round. By such means, a constant mutual attrition is produced between the two glasses, which is favoured by water and sands of several kinds bestowed between; sand still finer and finer being applied, as the grinding is more advanced; at last emery is used. We need not add, that as the upper or incumbent glass polishes and grows smoother, it must be shifted from time to time, and others put in its place.

It is to be noted, that only the largest size glasses are thus ground with a mill; for the middling and smaller sorts are wrought by the hand; to which end there are four wooden handles at the four corners of the upper stone or carriage, for the workmen to take hold of, and give it motion. What remains to the perfection of glass, comes under the denomination of *polishing*, which see.

Gun Flint

GUN Flint, in *Technological Mineralogy*. The mode of manufacturing gun-flints, as we have observed in the article **FLINT**, has for a long time been involved in fable and mystery: indeed, even in the *Mémoires de l'Académie de France*, we are told, "that there is never a deficiency of flints in those countries where they have once been found; that, as soon as a quarry appears exhausted it is shut up; and that when after a certain number of years it is re-opened, the flints are found there under the same circumstances as before." The same erroneous idea is repeated in the French *Encyclopédie*, and other works; and it was not till lately that we have been made fully acquainted (by Hacquet of Vienna and by Dolomieu) with the simple manner of manufacturing gun-flints in Galicia and France, where they constitute an important article of commerce. The latter of the above naturalists has given an account of it in the *Mém. de l'Institut National des Sciences (Classe Mathématique et Physique, t. 3. an. ix.)*; the former in a monograph on this subject, written in the German language.

In France, the best flints are found in the neighbourhood of St. Aignan, in the department of the Loir-et-Cher, and in that of the Indre, and the departments that occupy the vallies of Seine-et-Marne: they occur as horizontal banks in sletz-limestone, particularly chalk, and also in marle. Among twenty of such beds, or layers, situated one above the other at the distance of about twenty feet, there is generally only one, very seldom two, that furnish good gun-flints: all those of a good quality are coated with a white earthy rind. (See **FLINT**.) On the banks of the Cher, the flints are excavated by means of shafts of forty to fifty feet in depth, from whence levels or horizontal galleries are carried into the only good stratum which is known in that district; but on the banks of the Seine, in the hillocks of Rocheguyon, where the cliffs of chalks present broken precipices, the beds of flint are laid open to view: one of these beds, which contains the good sort, is at about six fathoms distance from the upper surface of the great mass of chalk.

The characters by which the good flints are distinguished from those less fit for being manufactured are the following: Their surface is rather convex, approaching to globular; those that are amorphous, or of a very irregular form, such as knobbed, branched, &c. are generally full of imperfections. Good flint nodules seldom exceed the weight of twenty pounds; nor are those that weigh less than one or even two pounds considered as being of a good quality. Internally they should appear unctuous and rather shining, with a grain too fine to be perceptible to the eye. The

colour may vary from honey-yellow to blackish brown; but the tint should be uniform in the same nodule. Their transparency should be sufficient to admit letters to be distinguished through a piece of the stone of a quarter of a line thick, laid close upon the paper. Their fracture should be perfectly smooth and equal throughout, and the fragments slightly conchoidal. The last of these properties is the most essential, since on it depends the facility with which the nodule is divided into gun-flints. All flints that prove deficient in any one of the above characters, either naturally or by a long exposure to the air, are called *intraçable*, and rejected by the workmen.

The tools made use of by the *caillouteurs* (a name given to the makers of gun-flints in France) are four in number: 1. A hammer or mace of iron with a square head (*Pl. II. Geology, fig. 1.*), the weight of which does not exceed two pounds; (but it may be of half that weight only,) with a handle of seven or eight inches long. This tool is not made of steel, for an excess of hardness would render the strokes too hard or dry (as the phrase is), and would shatter the nodules irregularly, instead of breaking them by a clear fracture.

2. A hammer with two points (*fig. 2.*) This is made of good steel, well hardened; its weight does not exceed sixteen ounces; indeed it may weigh ten ounces only. Its handle is seven inches long, passing through it in such a manner that the points of the hammer are nearer the hand of the workman, than the centre of gravity of the mass. The form and size of the hammers of different workmen vary a little; but this disposition of the points is common to them all, and is of consequence to the force and certainty of the blow.

3. The disk-hammer, or roller, a small tool, called in French *roulette*, which represents a solid wheel, or segment of a cylinder, two inches and four lines in diameter (*fig. 3.*): its weight does not exceed twelve ounces. It is made of steel not hardened, and is fixed on a handle six inches in length, which passes through a square hole in the centre.

4. A chissel tapering and bevelled at both extremities (*fig. 4.*), seven or eight inches long, and two inches wide, made of steel not hardened: this is set on a block of wood, which, at the same time, serves as a bench for the workmen.

To these four tools we may add a file, for the purpose of restoring the edge of the chissel from time to time.

After having selected a good mass of flint, the following four operations are performed by the workman.

1. *To break the block.*—The workman, being seated on the ground, places the nodule of flint on his left thigh, and applies slight strokes with the square hammer, to divide it

into smaller pieces of about a pound and a half each, with broad surfaces, and almost even fracture. The strokes should be moderate, lest the mass crack and split in the wrong direction.

2. *To cleave or chip the flint.*—The principal operation is to split the flint well, or to chip off scales of the length, thickness, and shape adapted, to be afterwards fashioned into gun-flints. In this part the greatest degree of address and certainty of manipulation are required. The fracture of the flint is not confined to any particular direction; it may be chipped in all parts with equal facility.

The workman holds the piece of flint in his left hand, not supported, and strikes with the pointed hammer, No. 2, on the edges of the great planes produced by the first breaking, by which means the white coating of the flint is removed in the form of small scales, and the mass of the flint itself laid bare in the manner represented, *fig. 5*; after which he continues to chip off similar scaly portions from the pure mass of the flint. These scaly portions are nearly one inch and a half wide, two inches and a half long; and their thickness, in the middle, is of about two lines. They are slightly convex below, and consequently leave in the part of the flint from which they were separated a space slightly concave, longitudinally bordered by two, rather projecting, straight lines or ridges, *fig. 6*. These ridges, produced by the separation of the first scales, must naturally constitute nearly the middle of the subsequent pieces; and such scales alone as have their ridges thus placed in the middle are fit to be made into gun-flints. In this manner the workman continues to split or chip the mass of flint in various directions, until the defects usually found in the interior render it impossible to make the fractures required, or until the piece is reduced too much to receive the small blows by which the flint is divided.

3. *To fashion the gun-flint.*—Five different parts may be distinguished in a gun-flint. 1. The sloping facet, or bevil part, which is impelled against the hammer of the lock of the gun: it is called by the French *mèche*. Its width should be from two to three-twelfths of an inch: if it were broader it would be too liable to break; and if more obtuse, the scintillation would be less brisk. 2dly. The sides, or lateral edges, which are always rather irregular. 3dly. The back, or the part opposite the tapering edge: this is the thickest part of the flint. The French call it *talon*.

4thly. The under surface, which is uninterrupted and rather convex. And, 5thly. The upper face, a small square facet between the tapering edge and the back, which receives the upper claw of the cock; it is slightly concave. The French term for it is *assis*.

In order to fashion the flint, those scales are selected that have at least one of the above-mentioned longitudinal ridges: the workman fixes on one of the two tapering borders to form the striking edge; after which, the two sides of the stone that are to form the lateral edges, as well as the part which is to form the back, are successively placed on the edge of the chisel in such a manner, that the convex surface of the flint, which rests on the fore-finger of his left hand, is turned towards that tool. He then, with the roulette, applies some slight strokes to the flint just opposite the edge of the chisel underneath; by which means the flint breaks exactly along the edge of the chisel.

4. The finishing operation is the trimming, or the process of giving the flint a smooth and equal edge; this is done by turning the stone, and placing the edge of its tapering end on the chisel, in which situation it is completed by five or six slight strokes with the roulette. This is termed *roffler* by the French workmen.

The whole operation of making a gun-flint is performed in less than one minute. A good workman is able to manufacture a thousand good chips or scales a day (if the flint nodules be of a good quality); and in the same manner he can fashion 500 gun-flints in a day; so that in the space of three days he is able to cleave and finish a thousand gun-flints without farther assistance.

This work leaves a great quantity of refuse, for scarcely more than half of the scales are good, and nearly half the mass in the best flints is incapable of being chipped out, so that it seldom happens that the largest nodules will furnish more than fifty gun-flints. Such scales as have a crust, or are too thick to be made into gun-flints, are used for the more common culinary purpose of striking a light. Those that are sold at Paris are brought from the banks of the Seine, and are generally of a brown colour.

The gun-flints are sorted out according to their perfection, and the use to which they are to be applied. They are classed into extra and common flints; flints for pistols, muskets, and fowling-pieces.

Gunpowder

GUNPOWDER, a composition of nitre, sulphur, and charcoal, mixed together, and usually granulated, which easily takes fire, and, when fired, rarefies, or expands, with great vehemence, by means of its elastic force.

It is to this powder we owe all the action and effect of guns, ordnance, &c. so that the modern military art, fortification, &c. depend almost wholly upon it.

It has been easily discovered, that saltpetre or nitre is not indispensibly necessary in the composition of gunpowder; and that it may be supplied by other substances. New gunpowder was some time ago made in France of double the strength of the old, without any nitre; and Dr. Hutton tried some of it in 1790 at Woolwich, and found that it was about double the strength of the ordinary sort. The substitute for nitre is the like quantity of the marine acid.

This, however, is an expensive article; and it is attended with the inconvenience of taking fire and exploding, from a very small degree of heat, and even without the aid of a spark. Some chemists have proposed to substitute for nitre the oxymuriat of pot-ash, and it has been found from experiments, sufficiently decisive, that gunpowder thus made exceeds with respect to energy of explosion the common powder. But oxymuriats act differently from mixtures with nitre; they exert their power suddenly and in a very small space, so as to be very destructive; but in projectile force they are inferior to gunpowder. These have also the dangerous quality of exploding with moderate friction. Some persons, misled by an experiment of Dr. Hales, which shews that burning sulphur does not generate elastic air, but diminishes the quantity of common air, have imagined that sulphur was an unnecessary and even injurious ingredient of gunpowder. But M. Beaumé has found by experiments, that the force of gunpowder was nearly doubled by addition of the sulphur. Sulphur, indeed, is not necessary for the explosion of gunpowder, as the other two ingredients, well mixed, will explode; but it serves to diffuse the fire instantaneously through the whole mass of powder. The advantage, however, of using sulphur seems, from some late experiments in France, applicable for increasing the force of explosion only to small charges; but in quantities of some ounces, the explosive, or at least the

projecting, force of powder without sulphur is as considerable as it is with it.

The invention of gunpowder is ascribed, by Polydore Virgil, to a chemist; who accidentally put some of this composition in a mortar, and covered it with a stone, when it happened to take fire, and blew up the stone.

Thevet says, the person here spoken of, was a monk of Fribourg, named Constantine Anelzen; but Belleforest, and other authors, with more probability, suppose him to be Bartholdus Schwartz, or the Black, who discovered it, as some say, about the year 1320; and the first use of it is ascribed to the Venetians in the year 1380, during the war with the Genoese; and it is said to have been first employed in a place anciently called Fossa Clodia, now Chioggia, against Laurence de Medicis; and that all Italy made complaints against it, as a manifest contravention of fair warfare.

But what contradicts this account, and shews gunpowder to be of an older era, is, that Peter Mexia, in his *Various Readings*, mentions that the Moors, being besieged in 1343 by Alphonfus XI. king of Castile, discharged a sort of iron mortars upon them, which made a noise like thunder; which is seconded by what Don Pedro, bishop of Leon, relates in his chronicle of king Alphonfus, who reduced Toledo, viz. that in a sea-combat between the king of Tunis, and the Moorish king of Seville, above four hundred and fifty years ago, those of Tunis had certain iron tubs or barrels, wherewith they threw thunder-bolts of fire.

Du-Cange adds, that there is mention made of gunpowder in the registers of the chambers of accounts in France as early as the year 1338.

Farther, it appears that our Roger Bacon knew of gunpowder near a hundred years before Schwartz was born. That excellent friar tells us, in his treatise "*De Secretis Operibus Artis & Naturæ, & de Nullitate Magiæ*," cap. 6. which is supposed by some to have been published at Oxford in 1216, and which was undoubtedly written before his *Opus Majus*, in 1267, "that from salt-petre, and other ingredients, we are able to make a fire that shall burn at what distance we please." Dr. Plott, in his "*History of Oxfordshire*," p. 236, &c. assures us, that these "other ingredients were explained in a MS. copy of the same

treatise, in the hands of Dr. G. Langbain, seen by Dr. Wallis, to be sulphur and wood coal." The writer of the life of Friar Bacon, in the *Biographia Britannica*, vol. i. says, that Bacon himself has divulged the secret of this composition in a cypher, by transposing the letters of the two words in chap. xi. of the above cited treatise; where it is thus expressed; "sed tamen salis petreæ lura mox can ubre (i. e. Carbonum pulvere) et sulphuris; et sic facies tonitrum & corruscationem, si scias artificium:" and from hence Bacon's biographer apprehends the words *carbonum pulvere* were transferred to the sixth chapter of Dr. Langbain's MS. In this same chapter Bacon expressly says, that sounds like thunder, and corruscations, may be formed in the air, much more horrible than those that happen naturally. He adds, that there are many ways of doing this, by which a city or an army might be destroyed; and he supposes that, by an artifice of this kind, Gideon defeated the Midianites with only three hundred men. (Judges, chap. vii.) There is also another passage to the same purpose, in the treatise "*De Scientia Experimentalia*." See Dr. Jebb's edition of the *Opus Majus*, p. 474.

Mr. Robins apprehends (see the preface to his *Traacts*), that Bacon describes gunpowder not as a new composition, first proposed by himself, but as the application of an old one to military purposes, and that it was known long before his time. Marcus Græcus, an ancient author, who probably lived about the time of the Arabian physician Mesue, in the beginning of the ninth century, and mentioned by him, in a treatise intitled "*Liber Ignium*," of which Dr. Mead had a MS. copy, and cited by Dr. Jebb in the preface to Bacon's *Opus Majus*, describes two kinds of fire-works; one for flying, inclosed in a case or cartouche, made long and slender, and filled with the composition closely rammed, like our modern rocket; and the other thick and short, strongly tied at both ends, and half filled, resembling our cracker; and the composition which he prescribes for both is two pounds of charcoal, one pound of sulphur, and six pounds of salt-petre, well powdered and mixed together in a stone mortar. See *CANNON*.

Mr. Dutens carries the antiquity of gunpowder much higher; and he refers to the accounts given by Virgil (*Æn. lib. vi. ver. 585.*), Hyginus (*Fabul. 61. and 650.*), Eustathius (ad *Odyss. l. 234. p. 1682. l. 1.*), Valerius Flaccus (*lib. 1. 662.*), and others, of Salmoneus' attempt to imitate thunder, presuming from hence that he used a composition of the nature of gunpowder. He adds, that Dion Cassius, in the "*Hist. Rom. in Caligul.*" p. 662, and Johannes Antiochenus, in "*Chronica*," apud Peiresciana Valesii, Paris, 1604, p. 804, report the same thing of Caligula. The Brachmans did the same, according to Themistius Orat. xxvii. p. 337. and also the Indians, whose practice is recorded by Philostratus, *Vita Apol. lib. ii. cap. 33.* See likewise lib. iii. cap. 13. Dutens's *Inquiry into the Origin of the Discoveries attributed to the Moderns*, p. 262, &c. Eng. ed. 1769.

See the preface to the *Code of Gentoo Laws*, 1776, where it is asserted, that gunpowder was known to the inhabitants of Hindoostan far beyond all periods of investigation.

GUNPOWDER, Preparation of. There are divers compositions of gunpowder, with respect to the proportions of the three ingredients, to be met with in pyrotechnical treatises; but the process of making it up is much the same in all.

For some time after the invention of artillery, gunpowder was of a much weaker composition than that now used by us, or that described by Marcus Græcus; which was chiefly

owing to the weakness of their first pieces. See *GUN* and *CANNON*.

Of 23 different compositions, used at different times, and mentioned by Tartaglia in his *Quef. and Inv. lib. iii. quef. 5.* the first, which was the most ancient, contained equal parts of nitre, sulphur, and charcoal. When guns of modern structure were introduced, gunpowder of the same composition with the present came also into use. The cannon powder, in the time of Tartaglia, was made of four parts of salt-petre, one of sulphur, and one of charcoal; and the musket powder of 48 parts of salt-petre, seven parts of sulphur, and eight parts of charcoal; or of 18 parts of salt-petre, two parts of sulphur, and three parts of charcoal. The cannon powder was in meal, and the musket powder grained; and it is certain that the invention of graining powder, which is a very considerable advantage, is a modern improvement. (See the preface to Robins's *Math. Traacts*, p. 32, &c.) The modern composition of it is six parts of nitre to one of each of the other two ingredients; though Mr. Napier says (*Transf. of the Irish Acad. vol. ii.*) that he finds the strength commonly to be the greatest with the following proportions, viz. 3lb. of nitre, about 9 oz. of charcoal, and about 4 oz. of sulphur: the proportion of ingredients in the powder of different nations and different manufactories has been very various. With us the government powder is the same for cannon and for small arms: the difference consisting only in the size of the grains: but in France there have been commonly enumerated three kinds of powder, viz. cannon-powder, musket-powder, and pistol-powder; of each of these again there are two sorts, a stronger and a weaker; all which differences arise only from the various proportions.

The proportions are thus: in the stronger cannon-powder, to every 100 pounds of salt-petre, 25 pounds of sulphur are generally allowed, with the same quantity of charcoal; and in the weaker cannon-powder, to every 100 pounds of salt-petre, 20 pounds of sulphur, and 24 pounds of charcoal. As for the stronger musket-powder, 100 pounds of salt-petre require 18 pounds of sulphur, and 20 of charcoal; and in the weaker, the proportional quantities are 100 pounds of salt-petre, 15 of sulphur, and 18 of charcoal. In the stronger pistol-powder, 100 pounds of salt-petre require 12 of sulphur, and 15 of charcoal; whereas the weaker has to 100 pounds of salt-petre only 10 of sulphur, but 18 of charcoal.

Other authors prescribe different proportions: Semienowitz, for mortars, directs 100 pounds of salt-petre, 25 of sulphur, and as much of charcoal; for great guns 100 pounds of salt-petre, 15 of sulphur, and 18 of charcoal; for muskets and pistols, 100 pounds of salt-petre, eight of sulphur, and ten of charcoal. Macquer, the author of the "*Dictionary of Chemistry*," recommends 75 parts of purified nitre, 15½ parts of charcoal, and 9½ parts of sulphur.

Miethius extols the proportion of one pound of salt-petre to three ounces of charcoal; or two, or two and a quarter, of sulphur: than which, he affirms, no gunpowder can possibly be stronger. He adds, that the usual practice of making the gunpowder weaker for mortars than guns, as in the example above, is without any foundation, and renders the expence needlessly much greater: for whereas to load a large mortar 24 pounds of common is required, and consequently to load it ten times, 240 pounds; he shews by calculation, that the same effect would be had by 180 pounds of the strong powder.

Mr. Napier has analysed the Chinese powder, and found the proportions of its ingredients to be nearly 100 of nitre, 18 of charcoal, and 21 of sulphur. It was large-grained,

not very strong, but hard, well coloured, and in good preservation. The French made many trials in 1756 at the royal manufactory of Essone, near Paris, for determining the best proportions of the component ingredients of powder. Of powder made with nitre and charcoal alone, 16 of nitre and four of charcoal yielded the strongest, and gave a power of 9 in the *eprouvette*. With all these ingredients, 16 of nitre, four of charcoal, and one of sulphur, raised the *eprouvette* to 15, and both a less and a greater quantity of sulphur produced a smaller effect. Then diminishing the charcoal, a powder of 16 of nitre, three of charcoal, and one of sulphur, gave a power of 17 in the *eprouvette*, which was the highest produced by any mixture. This last was also tried in the mortar *eprouvette* against the common proof powder, and was found to maintain a small superiority. The powder made without sulphur in the proportions above intimated was also tried in the mortar *eprouvette*, and with the following singular result: when the charge was only two ounces, it projected a 60lb. copper ball 213 feet, and the strongest powder with sulphur projected it 249 feet; but in a charge of three ounces the former projected the ball 475 feet, and the latter only 472 feet: and on the other hand the great inferiority of force in the smaller *eprouvette* of the powder without sulphur has been just noticed." Aikin's Dict.

When the several ingredients of gunpowder are properly prepared, mixed, and grained, in the manner already recited, if the least spark be struck thereon from a steel and flint, the whole will be immediately inflamed, and burst out with extreme violence.

The effect is not hard to account for: the charcoal part of the grain whereon the spark falls, catching fire like tinder, the sulphur and nitre are readily melted, and the former also breaks into flame; and at the same time the contiguous grains undergo the same fate. Now it is known, that saltpetre, when ignited, rarefies to a prodigious degree.

Sir Isaac Newton reasons thus on the point: the charcoal and sulphur in gunpowder easily take fire, and kindle the nitre; and the spirit of the nitre, being thereby rarefied into vapour, rushes out with an explosion much after the manner that the vapour of water rushes out of an *æolipile*; the sulphur also, being volatile, is converted into vapour, and augments the explosion: add, that the acid vapour of the sulphur, namely, that which distils under a bell into oil of sulphur, entering violently into the fixed body of the nitre, lets loose the spirit of the nitre, and excites a greater fermentation, whereby the heat is farther augmented, and the fixed body of the nitre is also rarefied into fume; and the explosion is thereby made more vehement and quick.

For if salt of tartar be mixed with gunpowder, and that mixture be warmed till it takes fire, the explosion will be greatly more violent and quick than that of gunpowder alone, which cannot proceed from any other cause than the action of the vapour of gunpowder upon the salt of tartar, whereby that salt is rarefied. See *Pulvis FULMINANS*.

The explosion of gunpowder arises, therefore, from the violent action whereby all the mixture being quickly and vehemently heated, is rarefied and converted into fume and vapour; which vapour, by the violence of that action, becomes so hot as to shine, and appear in the form of a flame.

Dr. Ingenhouz accounts for the effect of gunpowder, by observing that nitre yields by heat a surprising quantity of pure dephlogisticated air, and charcoal a considerable quantity of inflammable air; the fire employed to inflame the powder extricates these two airs, and sets fire to them at

the instant of their extrication. See this theory largely explained in Phil. Transf. vol. lxi. part ii. art. 26.

Count Rumford (see Phil. Transf. for 1797.) is of opinion that the force of the elastic fluid, generated in the combustion of gunpowder, may be satisfactorily accounted for upon the supposition that its force depends solely on the elasticity of watery vapour or steam. For this purpose he recurs to the experiments of M. Betancour, published at Paris, under the auspices of the Royal Academy of Sciences, in the year 1790, which shew that the elasticity of steam is doubled by every addition of temperature equal to 30° of Fahrenheit. From the count's reference it appears that the experiments were carried as far as 280° of that scale, in which case the pressure was found to be equal to about four atmospheres. He affirms, that there seems to be no reason why the same law should not hold in higher temperatures, and he has therefore extended his computations through 13 more terms of the geometrical series, the last of which affords an elastic force equal to more than 65,000 atmospheres. If, indeed, the deductions from M. Betancour's experiments be admitted, the water of crystallization in the nitre, and the moisture, which the charcoal may be conceived to retain, appear to be fully sufficient to account for the explosive force by means of steam only. The gasses produced by the explosion of gunpowder have not been analysed with accuracy since the discovery of all the variety of gasses with the basis of carbon: but they are certainly carbonic acid, sulphureous acid gas, and carburetted hydrogen. The residue is chiefly a sulphuret of potash formed by a part of the sulphur uniting with some of the alkali of the nitre, and hence proceeds the hepatic smell of a foul and damp gunbarrel. Aikin's Dict.

M. de la Hire, in the History of the French Academy for 1702, ascribes all the force and effect of gunpowder to the spring or elasticity of the air inclosed in the several grains thereof, and in the intervals or spaces between the grains; the powder being kindled, sets the springs of so many little parcels of air a playing, and dilates them all at once, whence the effect; the powder itself only serving to light a fire which may put the air in action; after which the whole is done by the air alone.

But it will appear from the experiments and observations of Mr. Robins, recited in the sequel of this article, that if this air be in its natural state at the time when the powder is fired, the greatest addition its elasticity could acquire from the flame of the explosion would not amount to five times its usual quantity, and, therefore, could not suffice for the two hundredth part of the effort, which is exerted by fired powder.

In order to understand the force of gunpowder, it must be considered, that whether it be fired in a vacuum or in air, it produces by its explosion a permanent elastic fluid. For if a red-hot iron be included in a receiver, and the receiver be exhausted, and the gunpowder be then let fall on the iron, the powder will take fire, and the mercurial gage will suddenly descend upon the explosion; and though it immediately ascends again, yet it will never rise to the height it first stood at, but will continue depressed by a space proportioned to the quantity of gunpowder which was let fall on the iron. By this means (firing small quantities at a time) the mercurial gage may be reduced from 29½ inches to 12½. Now this experiment, which has been often repeated, proves the proposition with respect to the production of a permanent elastic fluid in a vacuum; for the descent of the gage could only be effected by the pressure of some new generated fluid in the receiver, balancing in part the pressure of the external air. That this fluid, or

some part of it at least was permanent, appears from hence, that though in these experiments the quicksilver ascended after the operation, yet, next day it had ascended no higher than $22\frac{1}{2}$, at which place it seemed to continue fixed. And that this fluid is elastic, is proved from the descent of the mercurial gage; since the quantity of matter contained in this fluid could not by its gravity alone have sunk the quicksilver by the least sensible quantity; also from its extending itself through any space, however great, the experiment succeeding in either a large or small receiver, only the larger the receiver the less will be the descent of the mercurial gage to the same quantity of powder; the pressure of the generated fluid diminishing as its density diminishes. See Phil. Trans. No. 295.

The same production likewise takes place, when gunpowder is fired in the air; for if a small quantity of powder be placed in the upper part of a glass tube, and the lower part of the tube be immersed in water, and the water be made to rise so near the top, that only a small portion of air is left in that part where the gunpowder is placed; if in this situation the communication of the upper part of the tube with the external air be closed, and the gunpowder be fired (which may easily be done by a burning-glass) the water will, in this experiment, descend on the explosion, as the quicksilver did in the last, and will always continue depressed below the place at which it stood before the explosion; and the quantity of this depression will be greater, if the quantity of powder be increased, or the diameter of the tube be diminished. From whence it is proved, that as well in air as in vacuum, the explosion of fired powder produces a permanent elastic fluid. (Hauksbee, Phys. Mechan. Exp. p. 11.) This release of real and elastic air from various substances, in certain circumstances, is now a well known and incontestable fact. See AIR.

It also appears from experiment, that the elasticity or pressure of the fluid produced by the firing of gunpowder, is, *ceteris paribus*, directly as its density. This follows from hence, that if in the same receiver a double quantity of powder be let fall, the mercury will subside twice as much as in the firing of a single quantity. For the vapour produced from the double quantity, being contained in the same receiver, will be of double the density of that produced from the single quantity; whence the elasticity or pressure, estimated by the descent of the mercury, being likewise double, the pressure is directly as its density. Also the descents of the mercury, when equal quantities of powder are fired in different receivers, are reciprocally as the capacities of those receivers; and, consequently, as the density of the produced fluid in each.

To determine the elasticity and quantity of this elastic fluid, produced from the explosion of a given quantity of gunpowder, Mr. Robins premises, that the elasticity of this fluid increases by heat, and diminishes by cold, in the same manner as that of the air (a fact confirmed by some later experiments of Mr. Dalton); and that the density of this fluid, and consequently its weight, is the same with the weight of an equal bulk of air, having the same elasticity and the same temperature. From these principles, and from the experiments by which they are established, for a detail of which we must refer to the book itself, so often cited in these articles, he concludes that the fluid produced by the firing of gunpowder will be nearly $\frac{1}{3}$ of the weight of the generating gunpowder; and the ratio of the respective bulks of the powder, and the fluid produced from it, will be in round numbers, 1 to 244.

Count Saluce, in his Miscell. Phil. Mathem. Soc. priv. Taurin. p. 125, makes the proportion as 1 to 222, which,

he says, agrees with the computation of Messrs. Hauksbee, Amontons, and Belidor.

Hence we are certain, that any quantity of powder fired in any confined space, which it adequately fills, exerts at the instant of its explosion against the sides of the vessel containing it, and the bodies it impels before it, a force at least 244 times greater than the elasticity of common air, or, which is the same thing, than the pressure of the atmosphere; and this without considering the great addition which this force will receive from the violent degree of heat with which it is endued at that time; the quantity of which augmentation is the next head of Mr. Robins's enquiry. He determines that the elasticity of the air is augmented, when heated to the extreme heat of red-hot iron, in the proportion of 796 to 1944 nearly; and supposing that the flame of fired gunpowder is not less hot than red-hot iron, and the elasticity of the air, and consequently of the fluid generated by the explosion, being augmented by the extremity of this heat in the ratio of 1944 to 796, it follows, that if 244 be augmented in this ratio, the resulting number, which is 999, will determine how many times the elasticity of the flame of fired powder exceeds the elasticity of common air, supposing it to be confined in the same space which the powder filled before it was fired.

Hence then the absolute quantity of the pressure exerted by gunpowder at the moment of its explosion, may be assigned; for since the fluid then generated has an elasticity 999, or, in round numbers, 1000 times greater than common air; and since common air, by its elasticity, exerts a pressure on any given surface equal to the weight of the incumbent atmosphere, with which it is in equilibrio; the pressure exerted by fired powder, before it has dilated itself, is 1000 times greater than the pressure of the atmosphere, and, consequently, the quantity of this force on a surface of an inch square, amounts to above six tun weight; which force, however, diminishes, as the fluid dilates itself.

Though it has here been supposed, that the heat of gunpowder, when fired in any considerable quantity, is the same with iron heated to the extremity of a red heat, or to the beginning of a white heat, yet it cannot be doubted but that the fire produced in the explosion is somewhat varied (like all other fires) by a greater or less quantity of fuel; and it may be presumed, that according to the quantity of powder fired together, the flame may have all the different degrees from that of a languid red heat to the heat sufficient for the vitrification of metals; but as the quantity of powder requisite for the production of this last mentioned heat is certainly greater than what is ever fired together for any military purpose, we shall not be far from our scope, if we suppose the heat of such quantities as come more frequently in use to be, when fired, nearly the same with the strongest heat of red-hot iron; allowing a gradual augmentation to this heat in larger quantities, and diminishing it when the quantities are very small. Prin. of Gunnery, in Robins's Math. Tracts, vol. i. p. 59, &c.

Gunpowder is supposed to explode at about 600° Fahr. but if heated to a degree just below that of faint redness, the sulphur will mostly burn off, leaving the nitre and charcoal unaltered.

We may observe, that the variations of the density of the atmosphere do not any way alter the action of powder. By comparing several trials made at noon in the hottest summer sun, with those made in the freshness of the morning and the evening, no certain difference could be per-

ceived; and it was the same with those made in the night and in winter. Indeed, considering that the same quantity of that elastic fluid in which the force of powder consists, is generated in a vacuum and in common air, it is difficult to conceive how this force can be affected by the greater or less density of the atmosphere.

But the moisture of the air has a very great influence on the force of powder; for that quantity which in a dry season would communicate to a bullet the velocity of 1700 feet in one second, will not in damp weather communicate a velocity of more than 12 or 1300 feet in a second, or even less, if the powder be bad and negligently kept. Robins's *Math. Tracts*, vol. i. p. 101, &c.

This agrees with an experiment made before a committee of the Royal Society, where powder having been dried by being put into a phial placed in boiling water, threw a ball out of a mortar twice as far as the same quantity of powder taken out of the same barrel before it was dried.

Now the ranges under the same circumstances of charge, elevation, &c. being as the squares of the velocities of the ball, these velocities, in this experiment, will be to each other nearly as 17 to 12, which give ranges as 289 to 144. *Phil. Transf.* N° 465. p. 182, 183.

If powder be damp, shot made with equal quantities of it out of the same parcel, will differ considerably from each other, perhaps ten times more than if the powder was in good order. A small charge seems to lose a greater part of its force than a larger, each being equally damp. Another circumstance attending damp powder is, a remarkable foulness in the piece, after firing, much beyond what arises from an equal quantity of dry powder.

That powder will imbibed moisture from the air, and thereby increase in weight, is certain. A parcel of very good powder being placed on a white paper, pierced with a great number of fine holes, and held over the steam of hot water, the powder in half a minute was increased about $\frac{1}{5}$ in weight. Another parcel, continuing longer in the steam, was increased by $\frac{1}{4}$ part. That the moisture of the atmosphere has a like effect, appears from this, that an ounce of powder kept for some time in a room having a fire in it every day, being dried before the fire, lost above $\frac{1}{10}$ part of its weight; one third of which it regained in 1-1/2 than two hours by being removed to a part of the room distant from the fire. And as the air is often much moister than when this experiment was tried, and the open air is more moist than a room with a fire, it cannot be doubted but that the twentieth or thirtieth part of the substance of the best powder is water. Now as a certain quantity of water mixed with powder will prevent its firing at all, it cannot be doubted but every degree of moisture must abate the violence of the explosion; and hence the effects of damp powder are not hard to account for.

It is to be observed, that the moisture imbibed by powder does not render it less active when dried again. Indeed, if powder be exposed to the greatest damps, without any caution, or if common salts abound in it, as often happens through negligence in refining the nitre, the moisture it imbibes may, in such cases, be perhaps sufficient to dissolve some part of the nitre, which is a lasting damage that no drying can retrieve. But when tolerable care is taken in preserving powder, and the nitre it is composed of has been well purged from common salt, it will retain its force much longer than is usually supposed; and it is said that powder has been known to have been preserved for fifty years, without any apparent damage from its age.

Some care is necessary in the drying of damp gunpowder; for there is a degree of heat, which, though not sufficient to

fire the powder, will yet melt the brimstone, and destroy the texture of the grains. Nay, more, there is a heat with which the brimstone will flame and burn away gradually, and yet the powder will not explode; of this any one may satisfy himself by heating a piece of iron red-hot, and then throwing a few grains of powder on it at different intervals, during the time of its cooling; for by this means he will find, that at a certain time the separate grains that fall on the iron will not explode, but will burn with a small blue flame for some space of time, the grain still remaining unconsumed. Indeed, when it has begun to burn in this manner, it sometimes ends with exploding; but this more commonly happens when a number of grains lie near together; for then, though each separate flame is not sufficient to explode its respective grain, yet the whole fire made by them altogether grows strong enough at last to end in a general explosion; however, by attending to the proper temperature of the iron, and spreading the grain, two or three inches square may be covered with a blue lambent flame, which will last a considerable time without any explosion, and the grains afterwards will not apparently have lost either their colour or their shape. Now since these grains, when the brimstone is thus burnt or even melted out of them, will no longer act as powder; it is evident that powder may be spoiled by being dried with too violent a heat. Robins, *ubi supra*, p. 104, &c.

The velocity of expansion of the flame of gunpowder, when fired in a piece of artillery, without either bullet or other body before it, is prodigious. By the experiments of the author so often quoted, it seems this velocity cannot be much less than 7000 feet in a second. But M. Bernouilli and M. Euler suspect that it is much greater; and Dr. Hutton imagines that it cannot be less at the moment of explosion than four times as much. This, however, must be understood of the most active part of the flame. For, as was observed before, the elastic fluid, in which the activity of gunpowder consists, is only $\frac{1}{3}$ of the substance of the powder, the remaining $\frac{2}{3}$ will, in the explosion, be mixed with the elastic part, and will by its weight retard the activity of the explosion; and yet they will be so completely united, as to move with one common motion; but the unelastic part will be less accelerated than the rest, and some of it will not be carried out of the barrel, as appears by the considerable quantity of unctuous matter, which adheres to the inside of all fire arms after they have been used. These inequalities in the expansive motion of the flame, render it impracticable to determine its velocity otherwise than from experiments. The foundation of which determination is, that a barrel being fixed in a proper situation on a pendulum, such as is described under the head GUNNERY, and being charged with twelve penny-weight of powder, without either ball or wad, the powder being only put together by the rammer; on the discharge the pendulum ascended through an arch whose chord was 10 or 10 $\frac{1}{2}$ inches.

Now if the piece be again loaded with the same quantity of powder rammed down by a wad of tow, weighing one penny-weight, it may be supposed that this wad, being very light, will presently acquire that velocity, with which the elastic part of the fluid will expand itself when uncompressed; and it was accordingly found, that the chord of the ascending arch was by this means augmented to twelve inches; so that by the additional weight of one penny-weight of matter moving with the velocity, of the swiftest part of the vapour, the pendulum ascended through an arch whose chord was two inches longer than before. And by calculating upon these facts, and the principles laid down in his book, Mr. Robins determines that the velocity with which this one penny-weight of matter moved, must be about

7000 feet in one second. It is this prodigious celerity of expansion of the flame of fired gunpowder, which is its peculiar excellence, and the circumstance in which it so eminently surpasses all other inventions, either ancient or modern, for the purpose of military projections: for as to the quantity of motion of these projectiles only, many of the warlike machines of the ancients produced this in a degree far surpassing that of our heaviest cannon-shot or shells; but the great celerity given to these bodies cannot be in the least approached by any other means than by the flame of powder. The reason of this difference is, that the ancients could by weights, or the elasticity of springs and stretched chords, augment their powers to any degree desired; but then each addition of power brought with it a proportional addition of matter to be moved; so that as the power increased, those parts of the machine which were to communicate motion to the projectile, and were consequently to move with it, were likewise increased; and thence it necessarily happened, that the action of the power was not solely employed in giving motion to the impelled body, but much the greatest part of it was spent in accelerating those parts of the machine in which the power resided, to enable them to pursue the body to be projected with perpetual impulse, during its whole passage through the extent of their activity. Hence then it came to pass, that, though these ancient machines could throw enormous weights, they could project them but with small degrees of celerity, compared with what we can communicate to our cannon and musket-shot; whence in all operations, where these great velocities are useful, our machines are infinitely superior to those of antiquity; although, in more confined and shorter projections, these last have some advantage, which may yet render them worthy of the attention of those military geniuses, who have capacity enough to consider each part of the profession according to its true and genuine value, independent of the partial estimation of the times they live in. Ibid. p. 112.

There are several ways of proving the goodness of gunpowder. 1. By sight; for if it be too black, it is too moist, or has too much charcoal in it; so also if rubbed upon white paper, it blackens it more than good powder does: but if it be of a kind of azure colour, somewhat inclining to red, it is a sign of good powder. 2. By touching; for if in crushing it with your fingers' ends, the grains break easily, and turn into dust, without feeling hard, it has too much charcoal in it; or if in pressing under your fingers upon a smooth hard board, some grains feel harder than the rest, or, as it were, dent your fingers' ends, the sulphur is not well mixed with the nitre, and the powder is bad. And also by thrusting the hand into a parcel of powder, and grasping it, as if you were about to take a handful of it, you may feel if it be dry and equally grained, by its evading the grasp, and running mostly out of the hand. 3. By burning, in which method little heaps of powder are laid on white paper three inches or more asunder, and one of them fired; which, if it only fires all away, and that suddenly, and almost imperceptibly, without firing the rest, and makes a small thundering noise, and a white smoke arises in the air almost like a circle, the powder is good; if it leaves black marks, it has too much charcoal, or is not well burnt: if it leaves a greasiness, the sulphur or nitre are not well cleaned or ordered. Again, if two or three corns be laid on paper an inch distant, and fire be put to one of them, and they all fire at once, leaving no sign behind, but a white smoky colour in the place, and the paper not touched, the powder is good. So also if fired in a man's hand, and it burns not; but if black knots appear, which burn downwards in the place where proof was made, after firing, it is not strong

enough, but wants nitre. The method most commonly followed for this purpose with us, says Mr. Robins, is to fire a small heap of it on a clean board, and to attend nicely to the flame and smoke it produces, as likewise to the marks it leaves behind on the table; from all which instructive particulars the merit of the powder is ascertained with great accuracy, as is pretended: but besides this uncertain method, which how much soever it may be practised, none will undertake seriously to defend, there are, on particular occasions, other contrivances made use of, all which bear some analogy to the common powder-triers, sold at the shops: only they are more artfully fabricated, and instead of a spring they move a weight, which is a more certain and equal power.

Another method of proving gunpowder, is to take out of several barrels a measure, of about the size of a thimble, which is spread upon a sheet of fine writing paper, and then fired; if the inflammation is very rapid, the smoke rises perpendicularly, and the paper is neither burnt nor spotted, the powder is judged to be good: then two drams of the same powder, being exactly weighed, are put into a machine, called *eprouvette* or gunpowder prover, which, if it raises a weight of 24lb. to the height of $3\frac{1}{2}$ inches, it is allowed to be good.

But these machines, says Mr. Robins, though more perfect than the common powder-triers, are yet liable to great irregularities; for as they are all moved by the instantaneous stroke of the flame, and not by its continued pressure, they do not determine the force of the fired powder with that certainty and uniformity which were to be desired in these kinds of trials: and therefore, the method followed by the French, in the receiving of powders from the makers, seems to be much better. Their practice is thus:

They have, in each magazine, a small mortar cast with its bed, according to a determined pattern, which is the same throughout the kingdom: this mortar is always pointed at 45° , and it contains just three ounces of powder; and it is a standing maxim, that no powder can be received into their stores, unless three ounces of it, placed in the chamber of this mortar, throw a solid ball of $7\frac{1}{2}$ inches diameter to the distance of at least 55 French fathom. But if each barrel of powder was to be proved in this manner, the trouble of changing the mortar, &c. would be intolerable, and the delay so great, that no business of this kind could ever be finished. The method by firing against a pendulum, in the manner mentioned under the head GUNNERY, seems a readier way; but still it requires some nicety and time, which it were to be wished could be obviated. (Robins's *Mathemat. Tracts*, vol. i. p. 121.) Dr. Hutton has contrived a machine for this purpose, which has several advantages peculiar to itself. It is a small cannon, the bore of which is about one inch in diameter, and it is usually charged with two ounces of powder, and with powder only, as a ball is not necessary, and the strength of the powder is accurately shewn by the arc of the gun's recoil. The whole machine is so simple, easy, and expeditious in its use, that the weighing of the powder is the chief part of the trouble; and it is also so accurate and uniform, that the successive repetitions or firings with the same quantity of the same sort of powder, hardly ever yield a difference in the recoil of the smallest part of itself.

Count Rumford (see *Phil. Trans.* vol. lxxi.), having pointed out the insufficiency and the defects of the *eprouvettes*, or powder triers, in common use, recommends for proving the goodness and strength of powder, the following method: A quantity of powder being provided, which, from any previous examination or trial, is known to be of a proper

degree of strength to serve as a standard for the proof of other powder, a given charge of it is to be fired, with a fit bullet, in a barrel suspended by two pendulous rods, (according to the method which the author had previously described in the same paper,) and the recoil is to be carefully measured upon the ribbon. When this experiment has been sufficiently repeated, the mean and the extremes of the chords may be marked upon the ribbon by black lines drawn across it, and the word *proof* may be written upon the middle line; or if the recoil is uniform, then the *proof mark* is to be made in that part of the ribbon to which it was constantly drawn out by the recoil in the different trials. The recoil, with a known charge of standard powder, being thus ascertained, and marked upon the ribbon, let an equal quantity of any other powder, (that is to be proved,) be fired in the same barrel, with a bullet of the same weight; every other circumstance being alike; and if the ribbon is drawn out as far, or farther than the proof-mark, the powder is as good, or better than the standard; but if it falls short of that distance, it is worse than the standard, and to be rejected. For the greater the velocity is with which the bullet is impelled, the greater will be the recoil; and when the recoil is the same, the velocities of the bullets are equal, and the powder is of the same degree of strength, if the quantity of the charge is the same. And if care is taken in proportioning the charge to the weight of the bullet, to come as near as possible to the medium proportion that obtains in practice, the determination of the goodness of gun-powder from the result of this experiment cannot fail to hold good in actual service. The author has described his apparatus, and illustrated the construction and use of it by appropriate figures. Since the charges with the same kind of powder are as the squares of the velocities of discharged bullets, the charge of the weaker powder must be to that of the stronger, when the velocities are equal, as VV to vv ; V denoting the velocity of the bullet with the stronger powder, and v the velocity with the weaker, when the charges are equal, and the weight and dimensions of the bullet are the same, and when they are discharged from the same piece. The weaker powder therefore is as much worse than the stronger as VV is greater than vv ; or the comparative goodness of powder, of different degrees of strength, is as the squares of the velocities of the bullets when the charges are equal. The author, estimating the comparative goodness of government powder with that of double proof battle powder (see BATTLE), found, by the medium of several trials, that double proof battle powder is better than government powder in the proportion of 1.2036 to 1, or nearly of 6 to 5. But if instead of weighing the powder, we estimate the quantity of the charge by measurement, or the space it occupies in the bore of the piece, the comparative strength of battle powder will appear to be considerably greater, or its strength will be to that of government powder nearly as 4 is to 3; for the grains of this better kind of powder being more compact and nearly of a spherical form, a greater weight of it will lie in any given space than of government powder, which is formed more loosely, and of various and very irregular figures. Now the common price of double proof battle powder, as it is sold by the wholesale dealers in that commodity, is at the rate of 10*d.* per *cwt.* net, which is just two shillings per pound; while government powder is sold at 5*s.* 5*s.* per *cwt.*, or 1*s.* and $\frac{1}{5}$ of a penny per pound; but battle powder is better than government powder only in the proportion of 1.2036 to 1, or of 1*s.* 2*d.* to 1*s.* 6*d.*; battle powder is therefore sold at the rate of 10*d.* per lb., or 41 per cent. dearer than it ought to be; or those who make use of it in preference to government powder, do

it at a certain loss of 41 per cent. of the money that the powder costs them.

Gunpowder is a commodity of such consequence, both in respect of speculation, of war, and of commerce (the consumption thereof being incredible), that it will deserve a more particular detail. To make gunpowder duly then, regard is to be had, that the salt-petre be pure, and in fine large crystals or shootings; otherwise, it is to be purified, by taking away its fixed or common salt, and earthy part, thus: dissolve ten pounds of nitre in a sufficient quantity of fair water; settle, filtrate, and evaporate it in a glazed vessel, to the diminution of half, or till a pellicle appear on it; the vessel may then be taken off from the fire, and set in a cellar: in twenty-four hours the crystals will shoot, which separate from the liquor; and after the like manner may the liquor be crystallized several times, till all the salt be drawn forth; this done, put it into a kettle, and that on a furnace with a moderate fire, which gradually increase till it begins to smoke, evaporate, lose its humidity, and grow very white: it must be kept continually stirring with a ladle, for fear it should return to its former figure, whereby its greasiness will be taken away; after that, so much water is to be poured into the kettle as will cover the nitre; and when it is dissolved, and reduced to the consistency of a thick liquor, it must be stirred with a ladle without intermission, till all the moisture is again evaporated, and it be reduced to a dry and white meal. See the sequel of this article, and NITRAT of Potash.

The like regard is to be had to the sulphur, choosing that which is in large lumps, clear and perfectly yellow; not very hard, nor compact, but porous; nor yet too much shining; and if, when set on fire, it freely burns away all, leaving little or no residuum matter, it is a sign of its goodness; so likewise, if it be pressed between two iron plates that are hot enough to make it run, and in the running appear yellow, and that which remains of a reddish colour, it may be concluded to be fit for the purpose. But in case the same be foul and impure, it may be purified in this manner: melt the sulphur in a large iron ladle, or pot, over a very gentle coal fire, well kindled, but not flaming; then scum off all that rises on the top, and swims upon the sulphur; take it presently after from the fire, and strain it through a double linen cloth, letting it pass at leisure; so will it be pure, the gross filthy matter remaining behind in the cloth. See SULPHUR, and sequel of the article.

For the charcoal, the third ingredient, such should be chosen as is large, clear, and free from knots, well burnt and cleaving. See CHARCOAL.

The charcoal of light woods has been generally employed; but M. Beaumé affirms, from experience, that the charcoals of heavy and hard woods, if they have been well made, are as fit for the purpose. The charcoal not only concurs with the sulphur in supplying the inflammable matter, which causes the detonation of the nitre, but also considerably adds to the explosive power of the detonating nitre, by the quantity of elastic vapour expelled during its combustion.

Gunpowder being a mixture of sulphur and charcoal, which are very inflammable substances, with salt-petre, which in itself is not, if the salt-petre be too much in quantity, when compared with the other two, their burning may not be sufficient to consume the whole of the salt-petre; whence the fire may be less violent, and consequently the powder less vigorous, than if some of the salt-petre was taken away, and a like quantity of the other materials were added in its stead. On the other hand, if the salt-petre in the composition be less than what the burning of the other two sub-

stances can easily consume, the fire will be less active than it ought to be, because it is not augmented so much as it would be if a larger quantity of salt-petre had been added to the composition.

Hence it appears, that the goodness of powder is not to be estimated only from the quantity of salt-petre contained in it, although that substance seems to be the basis of the elastic fluid, in which its force consists: for since the converting of the salt-petre into that fluid, and the elasticity of the fluid, afterwards, depend in some measure on the violence of the fire produced at the explosion, it is plain that there is a certain proportion in the mixture of the materials, which will best contribute to this purpose, and consequently to the perfection of the powder.

What this proportion is, has been ascertained by experience; and it seems to be generally agreed, that in any quantity of powder, three-fourths of it should be salt-petre, the remaining one-fourth consisting of equal quantities of sulphur and charcoal. This is the proportion followed by the French, and by most nations in Europe: we, indeed, pretend to a greater degree of nicety in our proportions; though, it is said, they do not greatly differ from what is here mentioned; nor is it certain that they are preferable: this, however, may be depended on, that no methods of proving powder, hitherto generally practised in England, could at all ascertain the difference; and other powders made with the usual proportion, are nothing inferior to our's.

But it is not the due proportion of the materials only which is necessary to the making of good powder; another circumstance, not less essential, is the mixing of them well together; if this be not effectually done, some parts of the composition will have too much salt-petre in them, and others too little; and in either case there will be a loss of strength in the powder. Robins, *ubi supra*, p. 119, &c.

The actual mode of making gunpowder has been described in a very satisfactory manner by Mr. Coleman, of the royal powder mills of Waltham Abbey, in the 9th volume of the Philosophical Magazine, and cited in Aikin's dictionary. The ingredients are taken in the proportions of 75 of salt-petre, 15 of charcoal, and 10 of sulphur. The salt-petre is almost wholly that which is brought from the East Indies, and is refined by solution, evaporation, and crystallization. (See *NITRAT of Potash*.) It is then fused in a moderate heat, so as to expel the water, but none of the acid. By refining, the salt-petre is freed from those deliquescent salts, which would render it damp by keeping, and thus materially deteriorate it. The sulphur is such as is imported from Italy and Sicily, which is refined by melting and skimming, and if it be impure, by sublimation. The English sulphur requires expensive processes for purification, which exclude it from our manufactures of gunpowder. The charcoal formerly used in this manufacture near London, and which is still used in many parts of the world, was prepared in the usual mode of charring wood, by forming piles of it, covering it with sods or fern, and allowing it to burn with a slow smothering flame. But an improvement has been introduced, which serves, in a great degree, to constitute the superior excellence of English powder. The wood is cut into billets, about nine inches long and inclosed in iron cylinders, placed horizontally; and thus burnt gradually to a red heat, the fire being continued till the volatile parts are completely expelled, and the wood is thus completely charred. The pyroligneous acid is, however, preserved for use, by collecting it in pipes, that pass out of the iron cylinder and dip into casks, in which the acid liquor condenses. This acid is used in calico-printing, chiefly as the basis of some of the

iron liquors, and mordants for dark-coloured patterns. The wood, which, previously to charring, is barked, is generally either alder or willow, or dog-wood: but the difference of wood is said to be of no essential importance, provided that it be perfectly charred. The three ingredients above described, being duly prepared, are first separately ground into fine powder, then mixed in the requisite proportions, and afterwards committed to the mill for the thorough incorporation of their component parts. The powder-mill is a slight wooden building, with a boarded roof, so that in case of a moderate explosion, the roof may fly off without difficulty, and in the least injurious direction. Stamping-mills, which were formerly used, have been mostly set aside in our present manufactures, on account of the danger of over-heating, and the accidents attending it; and the business is now performed by two stones placed vertically, and running on a bed-stone, or trough. About 40 or 50 pounds of the mixed mass are laid upon this bed-stone, and moistened with water sufficient to reduce it, in the process of grinding, to a consistence considerably stiffer than paste, which experience ascertains to be the most eligible. The mills are worked either by water or horses. The composition, thus formed, is worked for about seven or eight hours, at least, in order to thoroughly incorporate and intermix the several ingredients, on which the quality of the powder very materially depends. The fine powder manufactured at Battle, in Sussex, is still worked in large mortars, or stamping-mills, with heavy pestles of lignum vitæ; but only a few pounds of the mass are wrought at a time. The next operation is that of "Corning," or graining; for which purpose it is sent to the "Corning-house." In this operation, which, however, is not essential to the manufacture of perfect gunpowder, and is only performed on account of the convenience of using it in grains rather than fine dust, the stiff paste is first pressed into hard lumps, and these are put into circular sieves with parchment bottoms, perforated with holes of different sizes, and fixed in a frame connected with a horizontal wheel. Each of these sieves is also furnished with a "runner," or oblate spheroid of lignum vitæ, which, being set in motion by the action of the wheel, squeezes the paste through the holes of the parchment bottom, forming grains of different sizes. The grains are then sorted, and separated from the dust by sieves of progressive dimensions. The grains are next "glazed," or hardened, and their rough edges taken off, by putting them into casks somewhat more than half full, which are fixed to the axis of a water-wheel, and by rapidly revolving, they are shaken against each other and rounded, and at the same time they receive a slight gloss or glazing. In this process much dust is separated from the grains.

The glazing is found to lessen the force of the powder from a fifth to a fourth (see Irish Transf. *ubi supra*); but it serves to preserve the powder from being injured by damp. When the powder has been corned, dusted, and glazed, it is dried in the "stove-house," where great care should be taken to avoid explosion. The stove-house is a square apartment, three sides of which are furnished with shelves or cases, on proper supports, arranged round the room, and the fourth contains a large cast-iron vessel, called a "gloom," which projects into the room, and is heated from the outside, so that no part of the fuel may touch the powder. For greater security against sparks by accidental friction, the glooms are covered with sheet copper, and are always cool when the powder is put in or taken out of the room. Here the grains are thoroughly dried, losing in the process what remains of the water added to the mixture in the mill, for bringing it to a working stiffness. This loss Mr. Cole-

man finds to be from three to five parts on 100 of the composition. The manufacture of the powder, when it is dry, is completed. The government powder for all sorts of ordnance, as well as for small arms, is usually made at the same time, and always of the same composition; the difference consisting only in the size of the grains, as they are separated by the respective sieves. A method of drying powder by steam-pipes, running round and crossing the apartment, has been successfully tried; and thus the possibility of any injurious accident from over-heating is prevented. The temperature of the room, when heated in the common way by a gloom-stove, is always regulated by a thermometer hung in the door of the stoves.

The powder should not be dried too hastily, or with too great heat; for in this case some of the sulphur sublimes out, (which it will do at a less heat than that which will inflame the powder,) and then the intimate mixture of the ingredients will be destroyed: and besides, the surface of the grain is hardened whilst the inner part is left damp.

Mr. Coleman deduces from experiment the following inferences: viz. "that the ingredients of gun-powder only pulverized and mixed have but a very small explosive force: that gunpowder granulated after having been only a short time in the mill, has acquired only a very small portion of its strength, so that its perfection absolutely depends on very long continued and accurate mixture, and incorporation of the ingredients:—that the strength of gunpowder does not depend on granulation, the dust that separates during this process being as strong as the clean grains:—that powder undried is weaker in every step of the manufacture than when dried:—and lastly, that charcoal made in iron-cylinders, in the way already mentioned, makes much stronger powder than common charcoal. This last circumstance is of so much consequence, and is so fully confirmed by experience, that the charges of powder now used for cannon of all kinds, have been reduced one-third in quantity, when this kind of powder is employed." The barrelling of powder is usually reserved for dry weather, as it is of great importance to avoid moisture.

Count Rumford (see Phil. Trans. vol. lxxi. pt. 2.) pursued the following method for determining the specific gravity of gunpowder. A large glass bucket, with a narrow mouth, being suspended to one of the arms of a very nice balance, and exactly counterpoised by weights put in the opposite scale, was filled first with government powder poured in lightly, then with the same powder shaken well together, afterwards with powder and water together, and lastly with water alone, and in each case the contents of the bucket were very exactly weighed. The specific gravity of gunpowder determined by these experiments is as follows:

Specific gravity of rain-water	-	-	1.000
Government powder, as it lies light in a heap,	}		0.836
mixed with air			
Government powder, well shaken together	-	-	0.937
The solid substance of the powder	-	-	1.745

Hence it appears, that a cubic inch of government powder shaken well together weighs just 243 grains; that a cubic inch of solid powder would weigh 442 grains; and consequently, that the interstices between the particles of the powder, as it is grained for use, are nearly as great as the spaces which these particles occupy. In his "Essays" the same ingenious philosopher estimates the specific gravity of gunpowder to be about 1.868.

To recover damaged powder, the method of the powder merchants is this; they put part of the powder on a sail-cloth, to which they add an equal weight of what is really

good; and with a shovel mingle it well together, dry it in the sun, and barrel it up, keeping it in a dry and proper place.

Others again, if it be very bad, restore it by moistening it with vinegar, water, urine, or brandy; then they heat it fine, searce it, and to every pound of powder add an ounce, an ounce and an half, or two ounces (according as it is decayed) of melted salt-petre; and afterwards these ingredients are to be moistened and mixed well, so that nothing may be discerned in the composition; which may be known by cutting the mass, and then they granulate it as aforesaid.

In case the powder be in a manner quite spoiled, the only way is to extract the salt-petre with water, according to the usual manner, by boiling, filtrating, evaporating, and crystallizing; and then, with fresh sulphur and charcoal, to make it up anew again.

GUNPOWDER, Laws relating to. By an act made in the 16 C. I. c. 21, all subjects may make and sell gunpowder, and bring into the kingdom salt-petre, brimstone, or any other material for the making of it. The erection of powder-mills, or the keeping of powder-magazines near a town, is a nuisance by the common law; for which an indictment or information will lie. By 12 G. III. c. 61, which reduces into one all former acts relating to the making, keeping, and carrying of gunpowder, no person shall use any mill or other engine for the making of gunpowder, in any place except in mills and other places where the manufacturing of gunpowder shall be actually carrying on at the time of the commencement of this act, or where it shall afterwards become lawful to carry on such manufacture by licence for that purpose; on pain of forfeiting all gunpowder otherwise manufactured; and 2s. for each pound. Nor under the same penalty shall any person, for the making of gunpowder, use any mill or engine worked with a pestle, commonly called a "Pestle-mill;" nor in any mill or engine make at any one time, under any single pair of mill-stones, any quantity of gunpowder, or materials to be made into gunpowder, exceeding 40lb; on pain of forfeiting all above 40lb., and also 2s. for each pound. This act does not extend to the powder-mills then erected in the parishes of Battle, Crowhurst, Seddlecombe, and Brede, in the county of Suffex, so far as relates to the making of such fine fowling gunpowder only, as is known by the name of "Battle powder." No person shall dry at any one time, in any one stove, &c. any quantity exceeding 40 cwt. on pain of forfeiting all above that weight, and 2s. per pound. No person shall keep in any corning-house, drying-house, dusting-house, or other place used in the making of gunpowder, or in any adjoining building, (except magazines or store-houses constructed with stone or brick, and situated, at least, 50 yards from the gunpowder mill,) any greater quantity of gunpowder than shall be necessary for the work then carrying on in such house or other place; on pain of forfeiting all the gunpowder above such necessary quantity, and 2s. for each pound. Manufacturers of gunpowder are to provide, besides the magazines and store-houses near their mills, a good and sufficient magazine remote from their respective mills, for the purpose of receiving and keeping all the gunpowder made at such mills, which magazine shall be built with brick or stone, near the river Thames, and below Blackwall, or in some other convenient place to be licensed by the justices; on pain of forfeiture of 25l. for every month, during which gunpowder shall be made without such magazine, and 5l. for every day during which they shall neglect to remove, with due diligence, the gunpowder made at such mill or adjoining magazine to the magazine so situated remote

from the mill. Every maker of gunpowder, who shall keep any charcoal within 20 yards of any mill or engine for the making of gunpowder, or of any drying, corning, or dusting-house, or any adjoining magazine or store-house belonging to it, shall forfeit 5*l.* for every week during which such charcoal shall be so kept. No person, being a dealer in gunpowder, shall keep at any one time more than 200*lb.* of gunpowder, and, not being a dealer, more than 50*lb.* in any house, &c. within the cities of London or Westminster, or within three miles of either of them; or within any other city, borough, or market town, or one mile thereof; or within two miles of any of the king's palaces, or any of the king's magazines; or half a mile of any parish church; or in any other part of Great Britain, except in mills or other places which, at the commencement of this act, shall be used for the making of gunpowder; on pain of forfeiting all the gunpowder above the quantity allowed to be kept, and the barrels, and also 2*s.* for every pound beyond the allowed quantity: provided that it shall be lawful for any person to keep, for the use of any mine or colliery, any quantity, not exceeding 300*lbs.* in any magazine or warehouse within 200 yards of such mine or colliery. However, it shall be lawful for the justices in sessions, from time to time, to license the erecting or having such mills and offices, or such magazines for keeping unlimited quantities of gunpowder in places, not being within London or Westminster, or any limits before described; and the justices, upon due application, and by due process of law, which the act states, may be ordered by the court of king's bench to grant such license. No person shall carry at any one time more than 25 barrels of gunpowder in any waggon, cart, or other carriage by land; or more than 200 barrels in any boat, barge, or vessel by water, except in vessels for importation or exportation; and the barrels shall be so secured that no part of the gunpowder shall be scattered in the passage; and each barrel shall contain no more than 100*lb.* of gunpowder; and when con-

veyed by land shall be entirely clofed in a leathern bag, or bags commonly called saltpetre bag; and every carriage shall be covered with a complete covering of wood, painted cloth, tarpaulin, &c.; and no gunpowder shall be carried in any boat, &c. that hath not a close deck, which shall be covered with raw hides or tarpaulins; on pain of forfeiture of the gunpowder and barrels, &c. which any person may seize for his own use on conviction of the offender. Justices are empowered to issue warrants for searching, in the day time, any house, mill, magazine, &c. or any carriage, ship, boat, &c. in which gunpowder is suspected to be made, kept, or carried, contrary to this act; and the searcher may seize such gunpowder and barrels. For security of ships on the river Thames, no master of any outward bound vessel shall receive on board more than 25*lb.* of gunpowder (except for the king's service) before the arrival of such vessel at or below Blackwall; and the master of every vessel coming into the river Thames shall (except in case of the king's service) put on shore in proper places all the gunpowder on board above 25*lb.*, either before the arrival of such vessel at Blackwall, or within 24 hours; on pain of forfeiting all the gunpowder above 25 pounds and barrels, and 2*s.* for every pound. The provisions of this act shall not extend to any mills or other buildings erected for making gunpowder in any lands belonging to his majesty, or to the keeping of gunpowder in any of his majesty's store-houses or magazines; or to hinder the trial of gunpowder by his majesty's officers; or to the carriage of gunpowder to or from the king's magazines; under a special order from the board of ordnance; or to the carriage of gunpowder with forces on their march, or with the militia during their annual exercise, or which shall be sent for the use of such forces and militia.

GUNPOWDER, in *Agriculture*, a material employed by the farmer for the purpose of blasting stones, &c. It has been lately found that the expence of this substance may be greatly lessened by the mixing of a portion of quick lime with it. See **BLASTING**.

Hammer

HAMMER, an instrument of iron, with a handle of wood; used, in most mechanic arts, to beat, stretch, drive, &c. Bodies capable of being stretched or extended under the hammer, are said to be *malleable*.

The Latins call it *malleus*, anciently *martulus* or *marculus*; by which name Pliny calls it when he says that Cyntra, son of Agrippa, invented the hammer and pincers. Hist. Nat. lib. vii. cap. 56. Vide Hardouin. Not. ad loc.

The hammers of our great forges are moved or worked by a water-mill.

HAMMER, in the *Manege*. See SHOEING-hammer.

HAMMER of a Clock. See CLOCK.

HAMMER, in *Anatomy*. See MALLEUS and EAR.

HAMMER-headed shark. See SHARK.

HAMMER, Yellow, in *Ornithology*. See EMBERIZA Citrinella.

HAMMER-hardened, in *Smithery*, is said of iron which is short or brittle, owing to its having been hammered when in a warm or due red heat, which is supposed to close its pores. Hammer-hardened iron, by being heated to a white heat, and suffered to cool gradually, again recovers its toughness. See HARDENING.

HAMMER-men, or Drivers, in *Mining*, are those colliers

who fall or wedge down the coals in a coal-pit, after the holers have undermined them, the processes of which are described in Mr. Farey's Report on Derbyshire, vol. i.

HAMMER-mills, or Forges, in the *Iron Manufacture*, are works in which very large tilt and forge hammers, worked by water-wheels or by steam engines, are used for working the iron, and drawing it out into bars. Smaller hammers of the same kind are used now for forging the articles of various manufactures; in the scythe factories, these are called skelpers, and are very common in the neighbourhood of Sheffield. The hammer-mill used by Mr. George Walby, trowel-maker of Goswell-street, is on a very curious construction; a view and description of which may be seen in the Transactions of the Society of Arts, vol. xxii. page 335.

HAMMER-pick, in *Mining*, is a strong pick with a hammer at one end, almost like that used by paviors, which is used in coal-pits, by the remblers, or colliers, who break the coals into sizable lumps, after they are fallen by the hammer-men, ready for the hurriers, or those who drag them to the shaft bottom. The whole process of working coals is described in Mr. Farey's Report on Derbyshire, vol. i.

Hardening

HARDENING, the act of communicating a greater degree of hardness to a body than it had before.

The hardening and tempering of iron and steel make a considerable article in the mechanical arts.

There are divers ways of effecting it : as by the hammer, quenching it when hot, in cold water ; case-hardening, &c. See **TEMPERING** and **STEEL**.

HARDENING, Hammer, is mostly used on iron and steel plates, for saws, springs, rules, &c.

HARDENING, Case, which is a superficial conversion of iron, into steel (see *CASE-hardening*) is thus performed : take cow horn or hoof, dry it well in an oven, and beat it to powder ; put as much bay-salt as of this powder into stale urine, or white-wine vinegar, and mix them well together ; cover the iron, or steel, all over with this mixture, and wrap it up in loam, or plate-iron, so as the mixture touch every part of the work ; then put it in the fire, and blow the coals to it, till the whole lump have a blood-red heat, but no higher ; lastly, take it out, and quench it. See **STEEL**, under which article other processes for this purpose are described.

HARDENING of the strata, in *Geology*, is a point on which theorists have been much divided : Dr. Hutton, and his commentator, Mr. Playfair, have contended, that fire or heat was necessary for the consolidation of the strata, after their deposit in a soft or pulverulent form, in the depths of the ocean.

Mr. Kirwan supposes this hardening to have been in part chemical, and to have followed immediately their deposition, and partly the effect of subsequent infiltration (*Geo. Essays*, p. 45.). While others have referred to desiccation or drying,

since the waters retracted, as alone sufficient to account for the hardening of the terrestrial strata. Those who attentively consider the vast mass and succession of different strata, which have been explored, below the level of, and even under the coasts of the ocean, as at Newcastle, Whitehaven, Borrowtowness, and in Cornwall, &c., will readily perceive, that drying, in its literal sense, by exposure to the air, as may be alleged with respect to the superficial strata of mountains, and to dry land in general, could have had no part in producing the induration or hardening of these sub-marine strata, and which, nevertheless, are found so exactly similar to the parts of the same strata exposed to the air, that the inference seems clear, that to the chemical principles which produced the deposition of the strata, is their hardening entirely to be ascribed.

HARDENING of Timber. The Venetians are famous for the soundness of their ships, which do not rot as those of other nations, but will endure much longer than the others. Tachenius tells us, that the whole secret of this consists in the manner of their hardening their timber intended for this service ; and that this is done by sinking it in water while green, and leaving it there many years. This prevents the alkali, or that salt which furnishes the alkali in burning, from exhaling afterwards ; and by this means the timber becomes almost as incorruptible as stone. It is evident that the exhaling of this salt, and the rotting of wood, have some very great connection with one another, since the more sound any piece of timber is, the more salt it proportionably yields ; and the wood which is rotten is found on trial to contain no salt at all. Tachen. Hippoc. Chym.

Hat

HAT, a covering for the head, worn by the men throughout the western part of Europe.

Hats are chiefly made of hair, wool, &c. worked, fulled, and fashioned to the figure of the head.

Hats are said to have been first seen about the year 1400, at which time they became of use for country wear, riding, &c. F. Daniel relates, that when Charles II. made his public entry into Rouen, in 1449, he had on a hat lined with red velvet, and surmounted with a plume, or tuft of feathers: he adds, that it is from this entry, or at least under this reign, that the use of hats and caps is to be dated, which henceforward began to take place of the chaperons and hoods that had been worn before. In process of time, from the laity, the clergy also took this part of the habit, but it was looked on as a great abuse, and several regulations were published, forbidding any priest, or religious person, to appear abroad in a hat without coronets, and enjoining them to keep to the use of chaperons, made of black cloth, with decent coronets; if they were poor, they were at least to have coronets fastened to their hats, and this upon penalty of suspension and excommunication. Indeed, the use of hats is said to have been of a longer standing among the ecclesiastics of Brittany, by two hundred years, and especially among the canons; but these were no other than a kind of caps, and from hence arose the square caps worn in colleges, &c.

Lobineau observes, that a bishop of Dol, in the twelfth century, zealous for good order, allowed the canons alone to wear such hats; enjoining, that if any other person come with them to church, divine service should immediately be suspended. Tom. i. p. 845.

Hats make a very considerable article in commerce: the finest, and those most valued, are made of pure hair of an amphibious animal, called the castor or beaver, frequent in Canada, and other provinces of North America. See **BEAVER**.

HATS, Method of making.—Hats, we have observed, are made either of wool, or hair of divers animals, particularly of the castor, hare, rabbit, camel, &c. The process is much the same in all: for which reason we shall content ourselves to instance in that of castors.

The skin of this animal is covered with two kinds of hair; the one long, stiff, glossy, and pretty thin set: this is what renders the skin, or fur, of so much value: the other is short, thick, and soft, which alone is used in hats.

To tear off one of these kinds of hair, and cut the other, the hatters, or rather the women employed for that purpose, make use of two knives, a large one, like a shoe-maker's knife, for the long hair; and a smaller, not unlike a vine-knife, wherewith they shave, or scrape off, the shorter hair.

When the hair is off, they mix the stuff: to one-third of dry castor putting two-thirds of *old coat*, i. e. of hair which has been worn some time by the savages, and card the whole with cards, like those used in the woollen manufactory, only finer; this done, they weigh it, and take more or less, according to the size or thickness of the hat intended. The stuff is now laid on the hurdle, which is a square table, parallel to the horizon, having longitudinal chinks cut through it; on this hurdle, with an instrument called a *bow*, much like that of a violin, but larger, whose string is worked with a little bow-stick, and thus made to play on the furs, they fly and mix together, the dust and filth at the same time passing through the chinks: this they reckon one of the most difficult operations in the whole, on account of the justice required in the hand to make the stuff fall precisely together, and that it may be every where of the same thickness. In lieu of a bow, some hatters make use of a sieve, or searce of hair, through which they pass the stuff.

After this manner they form gores, or two capades, of an oval form, ending in an acute angle at top; and with what stuff remains, they supply and strengthen them in places where they happen to be slenderer than ordinary; though it is to be remembered, that they designedly make them thicker in the brim, near the crown, than towards the circumference, or in the crown itself.

The capades thus finished, they go on to harden them into closer and more consistent flakes by pressing down a *hardening skin* or leather thereon; this done, they are carried to the *bason*, which is a sort of bench with an iron plate fitted therein, and a little fire underneath it; upon which laying one of the hardened capades, sprinkled over with water, and a sort of mould being applied thereon, the heat of the fire, with the water and pressing, imbeds the matter into a slight hairy sort of stuff, or felt; after which, turning up the edges all round the mould, they lay it by, and thus proceed to the other; this finished, the two next are joined together, so as to meet in an angle at the top, and only form one conical cap, after the manner of a *manica Hippocratis*, or flannel bag.

The hat thus basoned, they remove it to a large kind of receiver or trough, resembling a mill-hopper, going sloping or narrowing down from the edge or rim, to the bottom, which is a copper kettle, filled with water and grounds, kept hot for that purpose. On the descent or sloping side, called the *plank*, the basoned hat, being first dipped in the kettle, is laid, and here they proceed to work it, by rolling and unrolling it again and again, one part after another, first with the hand, and then with a little wooden roller, taking care to dip it from time to time, till at length, by thus full-

ing and thickening it four or five hours, it is reduced to the extent or dimensions of the hat intended. To secure the hands from being injured by this frequent rolling, &c. they usually guard them with a sort of thick gloves.

The hat thus wrought, they proceed to give it the proper form, which is done by laying the conical cap on a wooden block, of the intended size of the crown of the hat, and thus tying it round with a packthread, called a *commander*: after which, with a piece of iron or copper bent for that purpose, and called a *flamper*, they gradually beat or drive down the commander all round, till it has reached the bottom of the block, and thus is the crown formed; what remains at bottom, below the string, being the brim.

The hat being now set to dry, they proceed to *singe* it, by holding it over a flare of straw, or the like: then it is *pounded*, or rubbed over with pumice, to take off the coarser knap; then rubbed over afresh with seal-skin to lay the knap a little finer; and lastly, carded with a fine card to raise the fine cotton, with which the hat is afterwards to appear.

Things thus far advanced, the hat is set upon its block, and tied about with a packthread as before, to be dyed. The dyer's copper is usually very large, holding ten or twelve dozen of hats. The dye, or tincture, is made of logwood, verdigris, copperas, and alder-bark; to which some add galls and sumac.

In the manufacture of La Cote d'Or, says citizen Chauffier, (*Journal Polytechnique*, i. p. 160, &c.) the nut-gall is not used, and oak-bark has been substituted with advantage.

Here the hat is kept boiling for about three quarters of an hour; then taken out and set to cool, and then returned to the dye, and this for ten or twelve times successively. For the method of dyeing hats, see *DYEING of Hats*.

The dye being complete, the hat is returned to the hatter, who proceeds to dry it, by hanging it in the top or roof of a stove or oven, at the bottom of which is a charcoal fire; when dry, it is to be stiffened, which is done with melted glue or gum senegal, applied thereon by first smearing it, and beating it over with a brush, and then rubbing it with the hand. The next thing is to *steam* it on the *steaming bison*, which is a little hearth or fire-place, raised three feet high with an iron plate laid over it exactly covering the hearth; on this plate they first spread cloths, which being sprinkled over with water to secure the hat from burning, the hat is placed brim downwards thereon; when moderately hot, the workman strikes gently on the brim with the flat of his hand, to make the joinings incorporate and bind so as not to appear; turning it from time to time, this way and that way, and at last overturning and setting it in the crown.

When steamed sufficiently and dried, they put it again on the block, and brush and iron it on a table or bench for the purpose, called the *fall-board*; this they perform with a sort of irons like those commonly used in ironing linen, and heated like them, which being rubbed over and over each part of the hat, with the assistance of the brush, smoothes and gives it a gloss, which is the last operation; nothing now remaining but to clip the edges even with scissors, and sew a lining to the crown.

The several operations employed in hat-making, are separately described under the articles *FELTING*, *FULLING*, and *DYEING*, to which the reader is referred. The last operation, says Chauffier, (*ubi supra*), consists in lining the inner surface of the crown, as well as of the brim of the hat, with a glutinous substance, which in drying gives firmness to the work, and preserves its form. The usual composition is made of gum arabic, common gum, and Flanders glue, which are

dissolved together in a sufficient quantity of water, and brought to the requisite thickness by boiling. This preparation, simple and easy as it appears, is not indifferent with regard to the beauty and duration of the work. If it be too tenacious, it renders the stuff dry and brittle, and after some months use, a kind of greyish incrustation is formed on the surface, which alters the texture. "It appeared to me," (says Chauffier), that this effect was caused by the gum arabic which is added to the glue. I therefore sought among the plants of our own country for a simple preparation, which might be substituted instead of these natural and friable gums. The mucilaginous principle abounds in a great number of plants, and may be easily extracted by ebullition; and a gum may even be formed by evaporation, which preserves its suppleness and flexibility. These considerations induced me to recommend, instead of the usual preparation, a solution of glue in a decoction loaded with the mucilage of linseed oil. This preparation has been long used with economy in the manufactory, and with advantage in the excellence of the work. Since that time citizen Margueron having communicated to me his observations on the mucilage which may be extracted from the leaves of the horse-chestnut tree (*mafronier d'Inde*), and having ascertained how great a portion of mucous and adhesive matter these leaves afford, especially when the foliage is in its vigour; a strong decoction of these leaves has been used with much success to make the preparation with glue." Our author adds, that there are many other native plants which would be equally proper to afford facitious gums, and of which the use would be very advantageous.

HATS, Laws relating to. By 24 Geo. III. c. 51, all retailers of hats, commonly called felt or wool, stuff or beaver hats, or any leather or japanned hats, shall take out a licence from the stamp-offices, for which shall be paid within the bills, 40s., elsewhere 5s.; which licence shall be renewed annually, ten days before the end of the year. If any retailer shall sell any felt hats without a licence, he shall forfeit 50l.; and every person who shall sell any less quantity than one dozen of hats at one time to any one person, shall be deemed a retailer. Such person shall put over his door, or in the front of his house or shop, the words "dealer in hats by retail," on pain of forfeiting 40s.; and if an unlicensed person put up these words, he shall forfeit 50l. For every hat sold by a licensed retailer shall be paid the following duty: viz. if not exceeding the value of 4s. 3d.; above 4s. and not exceeding 7s. 6d.; from 7s. to 12s. 1s.; and above 12s., 2s. By 36 Geo. III. c. 125, all hats, previous to the delivery of them, shall be stamped on the lining; however, any licensed dealer may sell to any other of the same description any unstamped hats. The penalty for selling unstamped hats is 10l.; and for fixing stamped linings after they have been used, there is a penalty of 10l. and the same penalty also for receiving on sale, or wearing hats unstamped. Counterfeiting or forging of stamps is a capital felony. By 43 Geo. III. c. 68, for every hat, as above described, imported, shall be paid a duty of 1l. 1s., and on exportation shall be allowed a drawback of 10s. 6d. For the encouragement of the hat-manufacture, it is enacted by 24 Geo. III. c. 21. that no hare or coney skins shall be exported on the penalty of 500l. and forfeiture of the same; and every person assisting shall forfeit 40l. Dyeing such skins incurs a forfeiture of the same, and of 20l. For the further encouragement of the hat-manufacture, all goats' hair or Turkey goats' wool may be imported duty free.

HATS for women have been made in various forms, of silk, straw, shavings of wood, ivory, feathers, gold, and silver.

HAT

HAT is also figuratively used for the dignity of a cardinal, or a promotion to that dignity. In this sense they say, to expect a hat; to claim, or have pretension to the hat, &c.

Pope Innocent IV. first made the hat the symbol or cognizance of the cardinals; enjoining them to wear a red hat, at all ceremonies and processions, as a token of being ready to spill their blood for Jesus Christ. See **CARDINAL**.

Hull

HULL, or **KINGSTON-UPON-HULL**, in *Geography*, a borough, market-town, and sea-port in the East Riding of the county of York, England, is situated on the western side of the river Hull, and the northern bank of the river Humber, at the distance of about 25 miles from the mouth of the latter; nine miles S. of Beverley; 173 N. of London; and 38 S.E. of York. It extends nearly two miles in length, in a direct line, in which extent is included the adjoining parish of Sculcoates; and to rather more than half that distance in a parallel direction towards Beverley. The town originated in the year 1296, under the immediate patronage of king Edward I., who, on his triumphant return from Scotland, projected the foundation of a port, &c. at this place, then a small hamlet, called Wyke, and put his design immediately into execution. Peculiar privileges were granted to builders and residents, together with a royal charter, vesting the government in a warden and the body of freemen; and the new-formed town was distinguished by the appellation of Kingston, or Kingstown-upon-Hull. Edward founded a house of White friars, and caused a hall to be built for his own residence. This was probably given to the De la Poles, for soon afterwards a magnificent manor-house was erected by that wealthy family, which was frequently honoured with the royal presence, and falling to the crown by the attainder of Edmund de la Pole, earl of Suffolk, in 1508, became for some time the residence of king Henry VIII.

So rapid was the progress of the place, that, in about sixty years from its foundation, it was called upon to furnish king Edward III. with 16 ships and 466 men. In Leland's time it was a fair and well built town; and, according to Camden, it possessed stately edifices, strong fortresses, ships well equipped, a number of merchants, and abundance of all kinds of wealth; having been favoured with not less than sixteen charters from various successive monarchs. It was first fortified under a charter from king Edward II., and the walls repaired and strengthened with towers of brick in the time of king Richard II. by sir Michael de la Pole, who appears to have revived in this place the art of brick-making, which had fallen into disuse since the time of the Romans. King Henry VIII. built two block-houses and a citadel on the east bank of the river Hull, at an expense of 23,000*l.*, although he drew great part of the materials from the dissolved houses of Black and White friars, and the church of St. Mary. King Charles II., in 1681, laid out a vast sum in improving

the fortifications, which had suffered considerably from the severe siege of the town by the earl of Newcastle, and during the civil wars in the preceding reign. Within the last 35 years, the whole of these ancient works of defence, with the gates of the town, have been demolished, except two of the fortresses built by Henry, which, being guarded by several batteries and modern erections, are now converted into magazines, capable of containing more than 20,000 stand of arms, and ordnance stores for twelve or fifteen sail of the line, defended by a regular garrison,

Hull consists of three principal divisions, formed by the intervention of the docks, which, occupying the greater part of the space where the walls formerly stood, nearly insulate the old town. That on the north side of the old dock is in the parish of Sculcoates; all its buildings have been erected within the last thirty years, and form several spacious and handsome streets. A neat hall has been built for the administration of justice, &c. this part of the town being in the county of York, and not under the jurisdiction of the magistrates of Hull. The other division has arisen still more recently, and lies to the west of the Humber dock, occupying the situation of the ancient hamlets of Wyke and Myton; by which latter name it is now distinguished, and is included in the county of the town of Hull. A suburb also has lately sprung up, on the Holderness side of the river, in the parishes of Drypool and Sutton, encompassing the garrison, and connected with the town by a bridge of four stone arches, rebuilt in 1787, with a draw-bridge in the centre, which has this year (1811) been renewed on a very ingenious and novel construction, and is wide enough to admit the largest vessels that have occasion to pass through it. The whole town stands on a level tract of ground, within a short distance of the Yorkshire wolds; the principal streets are broad and well paved, and in lighting and watching it is not inferior to any place in the kingdom. A few years ago, it was computed that about 200 houses were built annually, but since the interruption to the Baltic trade, the principal source of revenue to this port, that number has been much diminished.

The edifices for religious worship belonging to the establishment are two parish churches, that of the Holy Trinity and St. Mary's; with a chapel of ease, and the chapels of the Trinity-house and Charter-house. The church of the Holy Trinity, a noble structure, was first erected in the reign of king Edward II.; the tower and west end were added about the time of king Henry VII., by whose successor, Hull

was made the see of a suffragan bishop, who possessed a stately palace in the High-street, long since destroyed. The church, however, remained under that of the neighbouring village of Hefle, until separated by an act of parliament in 1661. St. Mary's was formerly a much larger structure, and belonged to the priory of Ferriby. Great part of it, including the steeple, was pulled down by king Henry VIII. as obstructing the view from his palace. St. John's is a chapel of ease to the Holy Trinity, and was finished in 1792 at the sole expense of the Rev. Thomas Dikes, LL.B. the present incumbent. There are also various meeting-houses for the peculiar doctrines and worship of all the prevailing sects.

The charitable institutions in Hull are numerous. The most ancient and splendid is that of the Trinity-house, founded by subscription in 1369, and rebuilt in 1753: its funds have been progressively augmented by legacies and benefactions. It was incorporated by letters patent in the reign of Henry VI.; and its charters and grants have, at various subsequent periods, been renewed and extended. The fund is considerably increased by a monthly contribution of sixpence from every seaman sailing from this port; when superannuated, or disabled, they obtain relief, as do also their widows and children, from this charity. Several distinguished characters have been admitted to the freedom of this corporation, which is governed by wardens, brethren, and assistants. In a marine-school, connected with it, thirty-six boys are, for three years, clothed and educated for the sea service; the guild also provides North sea pilots for the royal navy, when required by government. The Charter-house hospital is worthy of particular notice; it was founded, together with an adjoining priory, by Michael de la Pole, for the support of a certain number of pensioners, denominated brothers and sisters; under the superintendence of a master, who enjoys a salary of 100*l.* per ann., with a house and garden. Several other smaller hospitals, for similar purposes, are distinguished by the names of the respective founders, *viz.* Lister's, Gregg's, Crowle's, Watton's, (bishop of St. David's,) Gee's, Harrison's, Ratcliff's, and Weaver hospitals. The workhouse is a large building, commonly known by the name of Charity hall. For the relief of the indigent sick and maimed, a general infirmary was erected, in 1782, by voluntary contributions, on a plan superior to most establishments of the kind, which has been the means of restoring to health near 9000 persons. Here are likewise a free grammar-school, founded by Alcock, bishop of Ely, in 1486, which enjoyed considerable reputation, especially under its late master the Rev. Jos. Milner, A.M.; the Vicar's-school, established by the Rev. W. Mafon, father of the poet of that name; a school for girls, and a valuable institution for putting out poor boys apprentices, endowed by Ald. Coggan, and another for orphans, endowed by Ald. Ferris. Two handsome buildings have also been recently erected, capable of containing 500 boys, and 250 girls, who are instructed with great success, according to the improved system of education. The chief part of the expense, as also that of several Sunday-schools and other charities, is defrayed by voluntary subscriptions.

Besides the various buildings already noticed, there are the custom-house, intended originally as an exchange also, but having been long disused for that purpose, the present comfortable room, with a news-room over it, was designed and executed in 1794, by and at the expense of an individual, though with a view to his ultimate advantage; the assembly rooms, not now adequate to the wants and opulence of the town; the gaol; the Neptune hotel; the Rodney and

Minerva lodges of Free-masons, the former of which is a most elegant and handsome room; the subscription library, founded in 1775, and built in 1800, a great advantage to the inhabitants, and containing many thousand volumes; and the theatre royal, rebuilt in 1809, a spacious and convenient structure, the interior of which is fitted up in a superior style of comfort and elegance. The avenue from the market-place to the Humber was lately widened, by taking down the guild hall, a mean brick building, and on its site shambles were erected, which, for convenience, elegance, and ventilation, may challenge comparison with any in the kingdom. The old shambles being likewise removed, the beautiful east end of Trinity church is again thrown open to the market-place, in the centre of which stands an equestrian statue of king William III. erected in 1734. Until a new guild hall shall be provided, the corporation transact business in a large house fitted up for the purpose. Among the public accommodations enjoyed by the inhabitants, may be reckoned the Barton-boats, which cross the Humber every tide, to and from Barton, a distance of about seven miles.

The commerce of Hull will be best appreciated by a statement of the annual exports and imports for a few years. The tonnage of this port was, several years ago, inferior only to that of London, Liverpool, and Bristol; its customs only to those of the former two. It sends at present nearly thrice as many ships to the whale fisheries as London, and, exclusive of the latter port, more than all Great Britain besides. Its facilities of communication with the interior, by means of the Ouse and Trent, and the canals communicating with them are very great. The gross amount of the customs was

	£.
In 1802	- 438,459
— 1803	- 379,675
— 1804	- 287,210
— 1805	- 386,070
— 1806	- 374,907
— 1807	- 340,825
— 1808	- 198,487
— 1809	- 276,811
— 1810	- 311,780

The number of ships (British and foreign) that entered inwards, and cleared outwards, from and to foreign parts, also of coasting-vessels, was,

	With Cargoes.		In Ballast.		Coasting Vessels.	
	Inwards.	Outwards.	Inwards.	Outwards.	Inwards.	Outwards.
1804	728	279	51	380	1560	1547
1805	658	232	47	327	1626	1602
1806	513	226	29	272	1576	1636
1807	525	158	9	335	1484	1614
1808	207	67	109	135	1557	1733
1809	473	256	55	223	1806	1938
1810	622	193	30	427	1786	2033

The dock was undertaken, according to act of parliament, in 1774, and completed within four years; the entrance is immediately from the river Hull; it extends in length about 600 yards; in width 85; and is 23 feet deep; is capable of containing 100 sail of square rigged vessels; and, with the wharfs and quay, occupies a space of more than thirteen acres; containing in the dock 48,188 square yards, in the quay 17,479; exceeding in capacity the largest in Liverpool, and now only surpassed by those of London: when made it was the largest in the kingdom. The subscribers to the dock are incorporated by the title of "The Dock Company at Kingston-upon-Hull." The original number of shares

was 120, but the trade of the port requiring further accommodation, two other acts of parliament were obtained in 1802 and 1805, by which the company was empowered to increase them to 180, the money arising from which, amounting to 82,390*l.*, was appropriated to the making of a new dock, which was completed under the title of the Humber dock, in 1809, at an expense of 220,000*l.* It opens into the Humber by a lock of excellent workmanship, large enough to admit a fifty-gun ship, crossed by an iron bridge in two parts, of very ingenious mechanism. The area of the dock and quays is ten acres, with a basin of four acres; its length 300 yards, width 114, and depth 29 feet; and it is intended to communicate with the old dock at some future time, which, when effected, will wholly insulate the old town. The company is entitled to certain duties on all ships entering the port; the profit divided on the shares was,

	£.	d.	£.	s.	d.
In 1805	14,733	0	98	4	6 per share.
— 1806	8,901	0	49	9	1 —
— 1807	8,290	0	46	1	2 —
— 1808	4,941	0	27	9	1 —
— 1809	7,872	0	43	14	9 —
— 1810	10,306	10	57	5	—

The manufactures of Hull are various and extensive; one of the principal branches is that of expressing and refining oil from linseed, and preparing the residue for feeding cattle: the process is chiefly effected by mills worked by the wind. The largest and finest mills in the kingdom of this kind, both for the above purpose and for grinding corn, are to be found in great numbers near this town; their machinery is excellent, and many of them are from 80 to upwards of 100 feet in height. An iron-foundry, two large sugar-houses, an extensive soap, and several white lead manufactories, Greenland yards, numerous dry-docks, shipbuilders' yards, and ropewalks, where a great number of hands are constantly employed; and several large breweries are amongst the most important, but do not comprize half the manufactories now existing in the town.

The entire civil authority over the town, and the several places within what is denominated the county of the town of Kingston-upon-Hull, a district of more than eighteen miles in circumference, west of it, is, by various royal charters, particularly those of king Henry VI. and king Charles II., vested in the corporation, which now consists of the mayor, the recorder, twelve aldermen, the sheriff, two chamberlains, a town clerk, a water-bailiff, and other officers, besides a high steward, who is generally some nobleman of rank. The

mayor is admiral of the Humber, and possessed of the power of life and death over criminals within his jurisdiction. The judges of assize visited this town, but of late years this has been discontinued, and all trials are removed to York, though causing a great additional expense to those concerned.

Hull returns two representatives to parliament: the right of election of whom, as well as of the several principal members of the corporate body, except the recorder and high steward, is vested solely in the burgesses or freemen of the town, an important body, amounting to upwards of 2000. The population returns to parliament in 1801, specified, that the town and county contained 4767 houses, occupied by 29,516 persons, of whom 13,051 were males, and 16,465 females: this does not include the adjoining populous parish of Sculcoates, nor the suburb on the east of the river Hull. A fair is held annually in October, and the markets are abundantly supplied, especially when the tide suits the Lincolnshire farmers to cross the Humber, on Tuesdays, Fridays, and Saturdays.

Hull has, at different times, given birth to men distinguished on various accounts. In the first rank must be placed her representative in parliament, that incorruptible patriot, Andrew Marvell, whose father was lecturer of Trinity church; and, in later times, a most worthy man and excellent poet, the Rev. W. Mason, A.M. son of the late vicar of the same. It likewise gave the titles of earl and duke, both now extinct, to the family of Pierrepont.

The village of Sculcoates, though not in the county, may justly be considered as forming a part of the town of Hull; a portion of the old dock is included within it. The church, situated towards the northern extremity of the parish, is a neat uniform structure, rebuilt in the year 1760, and contains some fragments brought from the neighbouring abbey of Meaux.

HULL *River*, in the East Riding of Yorkshire, is a small river, which falls into the Humber at the town of Kingston-upon-Hull, better known by the name of *Hull* only, and as being the fourth sea-port in point of importance in the British dominions. The Hull is made navigable from the Humber, about twelve miles, to Aike-beck mouth, the entrance of the Driffield navigation. See CANAL.

HULL and *Leven Canal*, is an inland navigation in Yorkshire, East Riding, made in pursuance of acts of parliament obtained in 1801 and 1805; it extends about three miles from the Hull river up to the town of Leven. See CANAL.

Hundreds

HUNDREDS, in the construction of reeds for weavers, denote the number of divisions in any given length of the reed. A thorough knowledge of the adaptation of yarn of a proper degree of fineness to any given measure of reed constitutes one of the principal arts of the manufacturer of cloth, as upon this depends entirely the appearance, and in a great degree the durability of the cloth when finished. The art of performing this properly is known by the names of *examining*, *setting*, or *fleying*, which are used indiscriminately, and mean exactly the same thing. The reed consists of two parallel pieces of wood of any given length, as a yard, a yard and quarter, &c. The divisions of the yard being into halves, quarters, eighths and sixteenths, the breadth of a web is generally expressed by a vulgar fraction, as $\frac{1}{2}$, $\frac{1}{4}$, $\frac{1}{8}$, $\frac{1}{16}$, and the subdivisions by the eighths or sixteenths or *nails*, as they are usually called, as $\frac{1}{8}$, $\frac{1}{16}$, &c. or $\frac{1}{8}$, $\frac{1}{16}$, $\frac{1}{32}$, &c. In Scotland the splits of cane which pass between the longitudinal pieces or ribs of the reed are expressed by hundred porters or splits. The porter is 20 splits, or $\frac{1}{4}$ th of an hundred. In Lancashire, Cheshire, and the other manufacturing counties of England, the divisions of the reed are different. A comparative table of the differences by which they are reduced, to the same standard as nearly as is possible, that is to say, within one split or division by which the Scotch or English manufacturer may at one glance ascertain the relation which the other modes of counting reeds bear to his own, is annexed to this article. In counting reeds by the number of hundreds in a determinate length, which is common to the manufacturers of the continent, as well as to those of Scotland, different lengths are used for the standard of fineness. In that part of France situated around Cambray, which is, or was, the principal seat of the cambric manufacture, the standard length of a reed, by which the fineness of the splits is ascertained, is 34 inches. In Holland, where the heavier fabrics of linen are chiefly produced, the standard of measure is 40 inches, and in Scotland the standard is 37 inches, or the Scottish ell. Now it is plain, that if 2000 or twenty hundred divisions or splits be contained in each of these respective measures, those which are contained in 34 inches must be finer and closer than those contained in 37, and still more so than those contained in 40. For the practical purposes of manufacture in this country it can be of little importance to ascertain with precision the relative proportions which these standards bear to each other, but to the wholesale purchaser it must be useful to have some correct idea of the mode by which both the value and quality of the commodity which he purchases may be ascertained

with considerable precision merely by inspection.

In Lancashire and Cheshire a different mode is adopted both as to the measure and divisions of the reed. The Manchester and Bolton reeds are counted by the number of splits, or, as they are there called, dents contained in $24\frac{1}{2}$ inches of the reed. These dents, instead of being arranged in hundreds, porters, and splits, as in Scotland, are calculated by what is there termed *bars* or *lears*, each containing 20 dents, or the same number as the porter in the Scotch reeds. Formerly the number of dents in a *bar* was frequently 19, a number so ill calculated for any easy arithmetical calculation, that it is difficult to conjecture the causes which could have suggested its adoption, unless we suppose that the number 19, in place of 20, was adopted to leave room for the shrinking-in breadth when first immersed in any liquid, to which all newly woven cloth is liable. The Cheshire or Stockport reeds again receive their designation from the number of ends or threads contained in one inch, two ends being allowed for every *dent*, that being the almost universal number in every species and description of plain cloth, according to the modern practice of weaving, and also for a great proportion of the fanciful articles. The number of threads in the warp of a web is generally ascertained with considerable precision by means of a small magnifying glass fitted into a socket of brass, under which is drilled a small round hole in the bottom plate of the standard, the number of threads visible in this perforation ascertaining the number of threads in the standard measure of the reed. Those used in Scotland have sometimes four perforations over any one of which the glass may be shifted. The first perforation is $\frac{1}{4}$ of an inch in diameter, and is therefore well adapted to the Stockport mode of counting, that is to say, for ascertaining the number of ends or threads per inch. The second is adapted for the Holland reed, being $\frac{1}{5}$ th part of 40 inches. The third is $\frac{1}{6}$ th of 37 inches, and is adapted for the now almost universal construction of Scotch reeds, and the fourth; being $\frac{1}{7}$ th of 34 inches, is intended for the French cambrics. Every thread appearing in these respective measures, of course, represents 200 threads or 100 splits in the standard breadth, and thus the quality of the fabric may be ascertained with considerable precision, even after the cloth has undergone repeated wettings, either at the bleaching ground or dye work. By counting the other way, the proportion which the woof bears to the warp is also known, and this forms the chief use of the glass to the manufacturer and operative weaver, both of whom are previously acquainted with the exact measure of the reed.

Comparative Table of 37-inch reeds, being the standard used throughout Europe, for linens, with the Lancashire and Cheshire reeds, and the foreign reeds used for Holland and cambric.

Scotch.	Lancashire.	Cheshire.	Dutch Holland.	French Cambric.
600	20	34	550	653
700	24	38	650	761
800	26	44	740	870
900	30	50	832	979
1000	34	54	925	1089
1100	36	60	1014	1197
1200	40	64	1110	1300
1300	42	70	1202	1414
1400	46	76	1295	1464
1500	50	80	1387	1602
1600	52	86	1480	1752
1700	56	92	1571	1820
1800	58	96	1665	1958
1900	62	104	1757	2067
2000	66	110	1850	2176

In the above table the 37-inch reed is placed first. It is called Scotch, not because it either originated, or is exclusively used, in that country. It is the general linen reed of all Europe, but in Scotland it has also been adopted as the regulator of her cotton manufactures. In the table it is only compared with the nearest English reed actually in use, for in most cases there is some small difference, which, however, is not material for practical purposes. For the Holland and cambric reeds, the exact number of splits or dents is given merely for comparison, as these reeds are not at all used in Britain.

The art of proportioning the yarn to the reeds, for different fabrics, has been always regulated by the practical experience of the manufacturer, and the taste or fancy of his customers. Some attempts have been made to reduce it to a standard, and it is evidently a matter of no difficulty. Without analyzing particularly the plans which have been proposed, and the arguments for and against each of them, it seems that the following may, in general, be taken as a good approximation.

Every species of yarn used in the manufacture of cloth, may be assumed to be a cylindrical body of stuff of a certain diameter. Now as the area of every circle is as the square of its diameter, and as the cubical content of every cylinder is found by multiplying the area of its base by its height, we may reasonably infer, that if the diameter of a thread is squared, and that square multiplied by its length, it will give the solid content, and *vice versa*; that the square root of the number which ascertains the weight of yarn, is a symbol of its diameter. If this be granted, it follows, that when any particular denomination of yarn is found to produce a proper fabric of cloth when woven in a reed of any given dimension, the proper denomination for any other reed may be found. Or if the yarn is at hand, and

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the proper reed wanted, it may be found by exactly the converse of the former analogy. Upon this hypothesis the analogy will be

As the square root of the given yarn,
Is to the given dimensions of the reed;
So is the square root of another kind,
To the dimensions of the reed required.

But as few practical manufacturers or weavers are accustomed to the extraction of roots, the real description of the yarn may be taken, and the reed squared, or multiplied into itself, which will give exactly the same result. It may be necessary to observe, however, in this place, that as the fineness of cotton yarn is ascertained by progressive numbers; and that of most other kinds of yarn, by the weight of certain quantities, the proportion or analogy in the former case must be direct, and in the latter inverse, because a diminution of weight in a given quantity necessarily implies an increase of fineness. The two following examples will, it is hoped, render this sufficiently obvious.

If a manufacturer finds, by experience, that a fabric of goods, such as please his customers, is produced by weaving N° 60 of cotton yarn in a reed of 1200 by the linen or Scotch reed, and wishes to ascertain what description of yarn he ought to employ for a web to be woven in a 1500 reed; the proportion will be

As 144, the square of the 1200 reed,
Is to 60, the number of the given yarn,
So is 225, the square of the 1500 reed,

To 94, the nearest integral number by calculation.

In the converse he would find the square of the reed, and would still find extraction of the root necessary.

But if a manufacturer of linen finds that a fabric of yarn, of any number of ounces to the spindle, is well adapted to a 1200 reed, and wishes to ascertain the weight or denomination of yarn fit for a 1500 reed as before, his proportion must be inverted.

The chief objection which practical men are apt to make to the above theory of adaptation, which is perhaps the best that has hitherto been found, is the following. That in finer fabrics of goods it is not found to produce the desired effect, and that experience proves, that were a practical manufacturer of cloth to adopt this rule implicitly, either his fine goods would be wanting in that show and elegance which is their chief recommendation, or that his coarse articles would be flimsy and deficient both in warmth and durability. Allowing to this objection, which is unquestionably well founded, in some respects, all the weight which it deserves, the answer to it is very easy. The chief recommendations of coarse goods are thickness and strength, those of fine goods lightness and elegance. These are not, nor can be regulated by any exact mathematical rule, as they are much dependant on fancy. No lady would expect, in a fine dress, the strength and durability of a sack, nor would any miller store his flour in a bag, possessing the principal requisites of a sieve. It is sufficient, if the manufacturer is enabled to obtain a fair proportion for the real fabric, and this he must afterwards vary, to suit his goods to the market for which they are intended.

Japanning

JAPANNING, the art of varnishing, and drawing figures on wood, &c. after the same manner as the workmen do who are natives of Japan.

The varnish made and used in China and Japan is composed of turpentine, and a curious sort of oil they have. This they mix and boil up to a proper consistence, and this never causes any swelling in the hands or face of the people who use it. The swellings in these parts, which often happen to those who work the lacquered ware, and sometimes to those who only pass by the shops of these people, is from the lack, and not the varnish. This lack is the sap or juice of a tree, which runs slowly out on cutting the lower part of the trunk of the tree, and is received in pots set on purpose under the incisions. The juice, as it flows from the tree, is of the colour and consistence of cream; and as it comes in contact with the external air, its surface becomes black. As they only use it when black, their method of preparing it is to set it out in the open air, in large flat bowls, in which it looks all surface; but that the whole may be of the same uni-

form colour, they continually stir it for twenty-four hours together, with a smooth piece of iron. By this means the whole becomes thicker than it was before, and of a fine deep black. When it is in this state, they powder some burnt boughs of trees, and mix them thoroughly with it; and then spreading it thin over any board which they intend to japan, it is soon dried in the sun, and is then absolutely harder than the board it is laid on. When this is thoroughly dry, they polish it over with a smooth stone and water, till it is as smooth as glass; and then wiping it very dry, they lay on the varnish, made of oil and turpentine, and boiled to a proper consistence for this kind of work.

If the work is to be of any other colour than black, that colour is to be mixed with the varnish, and then the whole spread on very thinly and evenly; for on this laying it on depends the principal art of varnishing. When there are to be figures in gold and silver, these must be traced out with a pencil in the varnish over the rest of the work; and when this varnish is almost dry, the leaf-gold or leaf-silver is

to be laid on, and polished afterwards with any smooth substance.

The substances which admit of being japanned are almost those of every kind that are dry, and not too flexible; as wood, metals, leather, and paper prepared. Wood and metals require no other preparation, except that of cleaning their surfaces, and rendering them perfectly even. But leather should be securely strained either on frames or on boards; and paper should be treated in the same manner, and have a previous strong coat of some kind of size; but it is rarely made the subject of japanning, till it is converted into *papier maché*, or wrought, by other means, into an inflexible form. One principal variation in the manner of japanning is the using or omitting any priming or under-coat on the work to be japanned. In the older practice, such priming was always used; and is at present retained in the French manner of japanning coaches and snuff-boxes of the *papier maché*. But in the Birmingham manufacture it has always been rejected. The advantages attending the use of such priming are, that it makes a saving in the quantity of varnish necessary to be used, and that it helps to form, by means of rubbing and water-polishing, an even surface for the varnish. However, when an under-coat of size is used, the japan coats of varnish and colour will be always liable to crack and peel off, and are less durable than those which are formed without such priming. This difference is observable in comparing the wear of the Paris and Birmingham snuff-boxes.

The laying in of the colours in varnish or oil instead of gum-water, is another variation from the method of japanning formerly practised. But if the colours are tempered with the strongest isinglass size and honey, instead of gum-water, and laid on very flat and even, the work will not be much inferior in appearance to that done by the other method, and will last as long as the common old japan work, the best kinds of the true japan excepted. The proper japan grounds are either such as are formed by the varnish and colour, where the whole is to remain of one simple colour; or by the varnish, either coloured, or without colour, on which some painting, or other decoration, is afterwards to be laid. The priming, or under-coat, which is sometimes used in japanning, is of the same nature with that called clear-coatings, practised by the house-painters; and consists in laying on and drying in the most even manner a composition of size and whiting. The common size, (see *SIZE*,) has been generally used; but in nicer works, the gloves or the parchment size, improved by adding a third of isinglass, will be preferable. The work should be prepared for this priming, by being well smoothed with fish-skin, or the glass-shaver; and by being brushed over once or twice with hot size diluted, when it is of the common strength, with two-thirds of water. The priming, formed of a size whose consistence is between that of the common kind and glue, mixed with as much whiting as will give it a sufficient body of colour to hide the surface on which it is laid, should be laid on evenly with a brush. Two coats of this priming will generally be sufficient; but if, upon trial with a fine wet rag, it will not receive a proper water-polish, another coat or more must be given it. And after the last coat but one is dry, the work should be smoothed by rubbing it with the Dutch rushes. When the last coat is dry, the water-polish should be given, by passing over every part of it with a fine rag, a little moistened, till the whole appears perfectly plain and even. The work is then ready to receive the painting or coloured varnish.

When wood or leather is to be japanned, without priming, it may be prepared by laying on two or three coats of coarse

varnish, made by dissolving two ounces of seed-lac, and as much rosin, in one pint of rectified spirit of wine; and then the proper japan-ground must be laid on. As metals never require to be under-coated with whiting, they must generally be treated in the same manner as wood or leather.

For white japan grounds.—Prepare a white varnish, by working and grinding flake white, or white lead, with a sixth part of its weight of starch, and drying the mixture; then temper it into a consistence fit for spreading with mastic varnish, (see *VARNISH*,) or compound it with gum anime; lay this on the body to be japanned, previously prepared with or without the under-coat of whiting; and varnish it over with five or six coats of the following varnish, formed by dissolving two ounces of the clearest and whitest grains of seed-lac, and three ounces of gum anime, pulverized, in about a quart of spirit of wine, and straining off the clear varnish.

A very good varnish, free from brittleness, may be obtained by dissolving as much gum anime as the oil will take in old nut or poppy oil, boiled gently when the gum is put into it. The ground of white colour may be laid on in this varnish, and then a coat or two of it may be put over the ground; but it must be well diluted with oil of turpentine when it is used.

Blue japan grounds may be formed of bright Prussian blue; or of verditer glazed over with Prussian blue, or smalt. The colour may be best mixed with shell-lac varnish, and brought to a polishing state by five or six coats of varnish of seed lac. But when a bright blue is required, and a less degree of hardness can be dispensed with, the method before directed, in the case of white grounds, must be pursued.

Red japan grounds.—For a scarlet ground, vermilion may be used; but this is less beautiful than the crimson produced by glazing it over with carmine or fine lake, or rose-pink. For a very bright crimson; instead of glazing with carmine, the Indian lake, called safflower, should be used, dissolved in the spirit of which the varnish is compounded. But in this case, instead of glazing with the shell-lac varnish, the upper or polishing coats need only be used; which will render this a cheaper method than the using of carmine. If the highest degree of brightness be required, the white varnishes must be used.

Yellow japan grounds.—For bright yellow grounds, king's yellow, or turpeth mineral should be used, either by themselves, or mixed with fine Dutch pink. The effect may be still more heightened by dissolving powdered turmeric root in the spirit of wine, of which the upper or polishing coat is made; which spirit of wine must be strained off from the dregs, before the seed-lac be added to it for forming the varnish.

Yellow grounds may likewise be formed of the Dutch pink only.

Green japan grounds may be produced by mixing king's yellow and bright Prussian blue; or turpeth mineral and Prussian blue. A cheap, but fouler kind may be had from verdigris with a little of the fore-mentioned yellows, or Dutch pink. But if a very bright green be wanted, the crystals of verdigris, called distilled verdigris, should be used, and their effect will be heightened by laying them on a ground of leaf-gold. Any of these may be used with good seed-lac varnish, but will be brighter with the white varnish.

Orange-coloured japan grounds may be formed by mixing vermilion or red lead with king's yellow, or Dutch pink; or orange lake, or red orpiment will make a brighter orange ground than can be produced by any mixture.

Purple japan grounds may be produced by the mixture of

lake and Prussian blue ; or a fouler kind, by vermilion and Prussian blue.

Black japan grounds may be formed, without heat, by either ivory-black, or lamp-black, which may be laid on with the shell-lac varnish : and the upper or polishing coat may be common seed-lac varnish.

For forming the common *black japan grounds* on iron or copper by means of heat, the work must be first painted over with drying oil, and a little lamp black ; and when it is moderately dry, put into a stove of such a degree of heat, as will change the oil black, without burning it. The heat should be slowly augmented and continued for a long time, in order to harden the coat of japan. This kind of varnish requires no polish.

Tortoise
 The best is made by means of the following varnish ; prepared by boiling together one gallon of good linseed oil and half a pound of umbre, till the oil becomes very brown and thick ; by straining the mixture through a coarse cloth, and setting it again to boil, till it acquires the consistence of pitch. On the piece of work to be japanned, well-cleaned, let vermilion, tempered with shell-lac varnish, or with drying oil diluted with oil of turpentine, be laid thinly on the places designed to imitate the more transparent parts of the tortoise-shell.

When the vermilion is dry, brush over the whole with the black varnish, tempered to a due consistence with oil of turpentine ; and when it is set and firm, put the work into a stove, where it may undergo a very strong heat, and be continued for a considerable time. This method, proposed in one of Kunkel's recipes, has been revived in the Birmingham manufactures, where it is pursued in forming the ground of snuff-boxes, dressing boxes, tea-waiters, &c. This ground may be decorated with painting and gilding in the same manner as any other varnished surface.

Japan-work ought properly to be painted with colours in varnish. (See *PAINTING in Varnish* and *VARNISH*.) The colours are now most frequently tempered in oil, having a fourth part of its weight of gum anime previously dissolved

in it. This oil should be well diluted with spirit of turpentine when it is used, that the colours may be laid more evenly and thin, and thus fewer of the polishing coats of varnish will be necessary. When water-colours are laid on grounds of gold, so as to have the effect of embossed work, they are best prepared by means of isinglass size corrected with honey or sugar-candy. The body of which the embossed work is raised may be formed of a very strong gum-water, thickened to a proper consistence by bole armeniac and whiting, in equal parts, which being laid on in the proper figure, and repaired when dry, may be then painted with the proper colours tempered in the isinglass size, or in the general way with shell-lac varnish.

The finishing part of japanning consists of laying on and polishing the outer coats of varnish. This is in general best done with common seed-lac varnish. (See *VARNISH*.) But where brightness is principally regarded, the seed-lac must give way to the whiter gums. When hardness, tenacity, and brightness are desired, the mixed varnish made of the picked seed-lac, already proposed under *white Japan grounds*, should be adopted. The pieces of work to be varnished should be placed near a fire, and made perfectly dry ; the varnish should then be rubbed over them with proper brushes ; first one coat, and when this is dry another should be laid over it ; and this operation must be continued at least five or six times. When a sufficient number of coats is thus laid on, the work is fit to be polished, which must be done, in common cases, by rubbing it with a rag dipped in tripoli, commonly called rotten-stone, finely powdered ; but toward the end of the rubbing, a little oil of any kind should be used with the powder : and when the work appears sufficiently bright and glossy, the oil alone should be used to clear it from the powder, and to give it a brighter lustre. For white grounds, fine putty or whiting should be used instead of the tripoli. For gilding of Japan work, see *Japanners GILDING*. Handmaid to the Arts, vol. ii. p. 497, &c.

Indigo Mills

INDIGO Mills. For the purpose of effecting the solution and union of indigo with the liquid used along with it, for the purposes of dyeing, mills of various constructions are in use. In this process trituration or friction is as much as possible avoided, and the pulverization is effected merely by bruising. For this two very sufficient reasons may be assigned; the first, in point of economy, and the second, to avoid chemical inconveniency. On whatever substance the indigo was trituated or rubbed, a certain proportion of the stuff would be mixed or incorporated along with the pulverized indigo, and that proportion of indigo which was absorbed by this stuff would be either totally lost, or brought into union with another substance which might prove useless, and probably injurious in the subsequent process of dyeing. If the former only was the case, the absorbed indigo would be totally lost; if the second took place, the whole process might be utterly spoiled by the combination. In the appropriate plate, *fig. 1.* represents the ground or horizontal plan of such an indigo mill as is generally used in small dye-works, and which is occasionally turned by a man's or boy's hand. This is tedious and laborious, for the operation must be continued for a very long time before the indigo is sufficiently mixed with the liquid to be fit for use, and only a small quantity can be put into the vessel at once. *Fig. 2.* is an elevated section of the same mill.

In this machine the pulverization or granulation of the indigo is effected by the pressure of a number of smooth cast-iron balls, like those used for the shot of great guns, which, being rolled among the indigo, press it into a paste by their weight, until it unites with the liquid by which it is to be held in solution.

In *fig. 1.* A represents the bottom and rim of the vessel which contains the indigo, and which is of a cylindrical form. B is an upright spindle, which, in this figure, does not appear. Upon the spindle B is fixed a wheel C C, with a convenient number of arms projecting round the vessel, like the radii of a circle; and below each of these arms are projecting pieces of iron, like the pins or teeth of a harrow, for moving the balls. When this wheel C is moved round its axis, the whole balls in the vessel A are set in motion, and, by rolling over the indigo, gradually press it, until it unites with the water or liquid with which it is surrounded. If the bottom of the cylinder be flat, a very small part of the surface of each ball can act upon the indigo; but by casting circular hollow grooves, as represented in *fig. 2.* nearly the semi-diameter of the ball will press upon the stuff. The mill is moved by a handle D, *fig. 2.* which sets in motion the small bevel wheel E, and this wheel acting upon the horizontal wheel F, fixed upon the spindle B, sets it also in motion, and consequently the wheel C C is moved round

its axis, and all the balls roll round upon the indigo. G is a cross shaft upon the top of the spindle B, loaded at each end with a heavy ball. There is generally another shaft placed at right angles to this, when they assist in regulating and equalizing the motion in the same manner as any other fly wheel. When the indigo is found to be sufficiently dissolved, and united with the water, the liquid thus formed is drawn off into any other vessel for use by means of a vent and spigot placed in any convenient part of the bottom of the vessel.

The great labour and time which it requires, and the small quantity of stuff which can be prepared at once by a machine of this kind, renders it ill adapted for the use of large works where much indigo is consumed, and where they have generally a horse-power water-wheel, or steam-engine, for raising water, cutting madder, and other purposes necessary in extensive works. *Fig. 3.* represents an elevated cross section of one of these machines, driven by any moving power, and capable of preparing a very great quantity of indigo at all times, as it requires no attendance, excepting to empty the vessel when the indigo is wanted, and add a fresh supply. H is a semi-circular vessel of cast-iron, placed upon a strong wooden frame O, and of any convenient length. I is a cover made in two pieces, with a circular aperture to admit the upright shaft K working upon the centre, or pivot P. At Q, the upright P is jointed to a horizontal shaft of wood M, the other end of which is connected by the joint R, with a crank fixed on the end of a horizontal shaft N driven by the moving power. The circular motion of the shaft and crank N communicates an alternate, or reciprocating motion, by means of the horizontal connecting shaft M, to the upper end of the upright shaft K, which vibrating upon the centre joint P, sets in motion the iron cylinders L, L, in the body of the vessel, which press upon the indigo, and produce the same effect, but to a much greater extent, as the balls in the machine first described. The cylinders L, L, may be made of any diameter or length which is found convenient. The greater mass of iron that they contain, the quicker and more effectual will be their operation upon the stuff, provided there is a sufficient power to drive them. The frame under the joint P extends the whole length of the semi-circular vessel H, which may be any length, according to the extent of the power and quantity of work required. As this machine requires no attention whatever, it is found very useful in large dye works, as, by means of it, they can constantly command a large supply of prepared indigo, which may be drawn off when wanted, for the longer it is under the preparing process, the better in every respect, and fresh indigo may be added as the supply gets low.

Ink

INK, a liquor wherewith to write on paper or parchment.

INK, Printing. See **PRINTING**.

INK, Writing, is commonly made of copperas and galls, and gum arabic; but other astringent plants may serve the same purpose; such as oak-bark, red roses, logwood, or fumach. Mr. Boyle seems to doubt whether all astringent vegetables will do the same.

Many are the preparations and methods of compounding the materials for making of writing ink. For many years the ink most generally used by European writers has been the infusion of galls and other astringent vegetables, containing gallic-acid, rendered black by sulphate of iron, and thickened by the addition of a little gum or sugar. This composition, however, is liable to fade; but since the discovery of the method of totally discharging the traces of common ink by the application of the oxygenated muriatic acid, more serious consequences are to be apprehended from the universal use of the common atramentous fluid, than the decay of its colour from age; for it is well known that, while the sulphate of iron remains on the paper, the colour of the writing may be restored by washing the MS. with fresh infusion of galls. We have several receipts in Nicholson's Philosophical Journal, vol. iv. p. 479, 4to., for composing ink capable of resisting the oxygenated muriatic acid.

Macquer, in the Chemical Dictionary, gives the following receipt for making good ink. In four French pints of common water or beer, let a pound of bruised galls be infused twenty-four hours without boiling; to this add six ounces of gum arabic; and when the gum is dissolved, six ounces of green vitriol, which will soon give it the black colour; the liquor is then to be strained through a hair-sieve.

The following method has been recommended by experience, and is easily and speedily practised. To a gallon of boiling water, put six ounces of blue galls, grossly pounded, and three ounces of copperas; stir the mixture well together, and then add six ounces of gum arabic pounded. After stirring the whole thoroughly, leave it to settle, and the next day strain it off from the dregs for use. See *INK lutea palustris*.

The following composition will make a very good black writing ink. Take a gallon of soft water, and boil in it a pound of chips of logwood for about half an hour; pour

the decoction boiling hot on a pound of the best Aleppo galls powdered, and two ounces of pomegranate peels, put into a proper vessel. After having stirred them well together with a wooden spatula, place them in the sunshine in summer, or within the warmth of any fire in winter, for three or four days, stirring the mixture occasionally; then add half a pound of green vitriol powdered, and let the mixture remain four or five days more, occasionally stirring it; and then add four ounces of gum arabic dissolved in a quart of boiling water; and after the ink has settled, strain it off through a coarse linen cloth, and keep it well stopped for use.

Mr. Delaval in his "Treatise on Colours," p. 37. informs us, that with an infusion of galls and iron filings, he had not only made an exceedingly black and durable ink, but by means of it, without the addition of any acid, dyed silk and woollen cloth of a good and lasting black. But this kind of ink, though the colour is far superior to that of any other, may be easily discharged, either by the smallest quantity of any acid, or even by simple water; because it doth not penetrate the paper in such a manner as is necessary to preserve it from the instantaneous action of the acid or of the water. During the action of the infusion of galls upon the iron in making this kind of ink, a very considerable effervescence takes place, and a quantity of air is discharged, the nature of which has not yet been examined.

Many of the more volatile kinds of oil may be used in writing, if reduced to a proper consistence by the addition of gum or resin. Tolerable ink may be made by dissolving 30 grains of common resin in 90 grains of oil of turpentine, and tempering the solution with 17½ grains of lamp-black, and 2½ of indigo. In a dry state, this composition resists the action of water, but not of spirit. Copal is much superior to resin; it will dissolve in only few liquids. It may be dissolved, however, in oil of lavender. The only inconvenience attending the use of copal in the composition of ink is, that it is soluble at a low temperature. Ink may be composed of oil of lavender, copal, and lamp-black in the manner following: Take oil of lavender 200 grains, copal, in powder, 25 grains, and lamp-black from 2½ to 3 grains. With the assistance of a gentle heat, dissolve the copal in the oil of lavender in a small glass phial, and then mix the lamp-black with the solution upon a marble slab, or other smooth surface. Put the composition into the bottle, and keep it from the air. After the repose of some hours, the ink must be

well shaken, and stirred with a piece of wire before it is used ; if it be too thick, it must be diluted with a little oil of lavender, oil of turpentine, or alcohol. The facility of writing with this composition depends much on the quantity of the colouring matter. Nicholson's Journal, vol. ii. 8vo.

As the duration of records, and other valuable writings, depends much on the goodness of the ink employed, Dr. Lewis has thought this subject worthy of his attention. The chief imperfection of common inks is, that they decay in time, and at last the writing becomes invisible. From experiments made by that author, he infers, that the decay of inks is chiefly owing to a deficiency of galls ; that the galls are the most perishable ingredient, the quantity of these, which gives the greatest blackness at first (which is about equal parts with the vitriol) being insufficient to maintain the colour ; that for a durable ink, the quantity of galls cannot be much less than three times that of the vitriol ; that it cannot be much greater without lessening the blackness of the ink ; that by diminishing the quantity of water, the ink was rendered blacker and more durable ; that distilled water, rain water, and hard spring-water, had the same effects ; that white wine produced a deeper black colour than water ; that the colour produced by vinegar was deeper than that by wine ; that proof spirit extracted only a reddish-brown tinge, and rectified spirit a paler brown ; that the last mentioned tinctures sunk into, and spread upon the paper ; and hence the impropriety of adding spirit of wine to ink, as is frequently directed, to prevent mouldiness or freezing ; that other astringents, as oak bark, bistort, sloe-bark, &c. were not so effectual as galls, nor gave so good a black, the colour produced by most of these, excepting oak-bark, being greenish ; that the juice of sloes did not produce a black colour with martial vitriol ; but that, nevertheless, the writing made with it became black, and was found to be more durable than common ink ; that inks made with saturated solutions of iron in nitrous, marine, acetous acids, in tartar, or in lemon juice, were much inferior to the ink made with martial vitriol ; that the colour of ink was depraved by adding quicklime, which was done with an intention of destroying any superabundant acid which might be supposed to be the cause of the loss of the colour of the ink ; that the best method of preventing the effects of this superabundant acid is probably by adding pieces of iron to engage it ; and that this conjecture was confirmed by an instance the author had heard, of the great durability of the colour of an ink in which pieces of iron had been long immersed ; and lastly, that a decoction of logwood used instead of water, sensibly improved both the beauty and deepness of the black, without disposing it to fade. The same author observes, that the addition of gum arabic is not only useful, by keeping the colouring matter suspended in the fluid, but also by preventing the ink from spreading, by which means a greater quantity of it is collected on each stroke of the pen. Sugar, which is sometimes added to inks, was found to be much less effectual than gums, and to have the inconvenience of preventing the drying of the ink. The colour of ink is found to be greatly injured, by keeping the ink in vessels made of copper, or of lead, and probably of any other metal excepting iron, which the vitriolic acid can dissolve. The foregoing experiments point out for the best proportions of the ingredients for ink ; one part of green vitriol, one part of powdered logwood, and three parts of powdered Aleppo, or blue galls. The best menstruum appears to be vinegar or white wine, though for common use water is sufficient. If the ink be required to be of a full colour, a quart, or at most three pints, of liquor may be allowed to three ounces of galls, and to one ounce of each of the

other two ingredients. Half an ounce of gum may be added to each pint of the liquor ; though the more gum we can employ, consistently with due freedom of writing, it is probable that the ink will be the more durable. The ingredients may be all put together at once in a convenient vessel, and well shaken four or five times each day. In ten or twelve days the ink will be fit for use, though it will improve by remaining longer on the ingredients ; or it may be made more expeditiously, by adding the gum and vitriol to a decoction of galls and logwood in the menstruum. To the ink, after it has been separated from the feculencies, some coarse powder of galls, from which the fine dust has been sifted, together with one or two pieces of iron, may be added, by which its durability will be secured.

It has been often remarked, says the same ingenious writer, that the inks used in former times were far more durable than those of later years ; many modern records being more decayed than manuscripts of much greater antiquity, of which we have instances in the Letters of Camillo Paderni, published in the Philosophical Transactions for 1753 and 1754. Dr. Lewis made several experiments, in order to recover the composition of this durable ink. Instead of oil which is used in the printers' ink, he mixed both lamp-black and ivory-black with a solution of gum arabic ; this liquor wrote of a fine black colour, but when dry, it rubbed off entirely by moisture. Concluding, therefore, that the colour could not be sufficiently fixed on paper without an oily cement, and as oils are made miscible with watery fluids by the intervention of gum, he mixed some of the softer printers' varnish with about half its weight of a thick mucilage of gum arabic, working them well together in a mortar, and beat this mass with lamp-black, adding water by little and little, and continuing the rubbing, till the mixture became of a due consistence for writing. This produced characters of a full brownish black colour, which could not be discharged by rubbing, nor washed out so readily as the foregoing. Instead of the printers' varnish, or boiled oil, linseed-oil was mixed in the same manner with mucilage and lamp-black, and the mixture diluted with water ; and the ink thus obtained was much the same as the other. To prevent the discharge by water, some of the more sinking kinds of paper, or common paper made damp as for printing, must be used, which will admit the ink to sink a little into its substance ; and thus the characters will be as fixed as can be desired. Such Dr. Lewis found to be the ancient inks, that were so durable. Pliny and Vitruvius expressly mention the preparation of foot, or lamp-black, and the composition of writing ink from lamp-black and gum. Dioscorides sets down the proportion of three ounces of the foot to one of gum. This mixture was formed into cakes or rolls, and dried in the sun, which were occasionally tempered with water, as the Indian ink is with us for painting. The ancients were sensible that these inks were liable to be discharged by water, and endeavoured to obviate this imperfection, according to Pliny, by using vinegar, instead of water, for tempering the mixture of lamp black and gum, which promotes the sinking into the paper. After all, none of these inks can be discharged otherwise than by design ; which is the case with respect to the vitriolic inks, and those of printed books and copper-plates.

In the course of Dr. Lewis's experiments, a farther improvement occurred to him, which was that of using the common vitriolic ink, instead of water, for tempering the ancient mixture of gum and lamp-black. By this method the writings will have the durability of those of former times, with all the advantage that results from the vitriolic ink fixing itself in the paper. Common writing ink may, in

many cases, be improved by a small addition of the ancient composition, or of the common Indian ink. Lewis's *Commerce of Arts, &c.* § 16.

Mr. Astle, in his "Origin of Alphabetical Writing," inculcates the necessity of making ink durable; and for this purpose suggests a comparison of the rolls and records that have been written from the 15th century to the end of the 17th, with the writings that remain from the 5th to the 12th centuries. These are in excellent preservation; but the former, though of more modern date, are defaced to such a degree that they are scarcely visible. Mr. Astle agrees with Dr. Lewis in the opinion, that the ancient inks were composed of foot or ivory black instead of the galls, copperas, and gums, which form the composition of ours. Besides their black ink, the ancients used various other colours, as red, gold and silver, purple, &c. Green ink was frequently used in Latin MSS., especially in the latter ages: and it was frequently employed in signatures by the guardians of the Greek emperors till their wards were of age. Blue or yellow ink was seldom used except in MSS., but, according to Mr. Astle, the yellow has not been much in use for these 600 years. Some kinds of characters, particularly the metallic, were burnished. Wax was used by the Latins and Greeks as a varnish, especially by the former, and particularly in the 9th century. This continued a long time in vogue. Dr. (Sir Charles) Blagden, in the *Phil. Transf.* vol. lxxvii. p. 451, &c. has proposed a new method of recovering the legibility of decayed writings. With this view he made some experiments on parchment and vellum MSS., with which he was furnished by Mr. Astle, employing those chemical re-agents which seemed best adapted to his purpose, viz. alkalies, both simple and phlogisticated, the mineral acids, and infusion of galls. The general result shewed, that the ink anciently used, at least in these MSS., was of the same nature as the present; and the greater durability of the more ancient inks appeared to depend very much on a better preparation of the material upon which the writing was made, viz. the parchment or vellum. He suspected, however, that the ancient inks contained a rather less proportion of iron than the more modern; and perhaps more gum was used then, or possibly they were washed over with some kind of varnish, though not such as gave any gloss. It occurred to our author, in the course of his experiments, that perhaps one of the best methods of restoring legibility to decayed writings might be to join phlogisticated alkali with the remaining calx of iron. In order to bring this idea to the test, he made several experiments, for which we refer to his paper, *ubi supra*. The method now commonly practised to restore old writings is the wetting of them with an infusion of galls in white wine. This has certainly a great effect: but, like the phlogisticated alkali, it is apt to stain the substance in which the writing was made. Sir Charles Blagden suggests, that a phlogisticated alkali, better adapted to this purpose than the common, might be prepared, by rendering it as free as possible from iron, diluting it to a certain degree, or substituting the volatile alkali for the fixed. This would serve to bring out a prodigious body of colour upon letters which were before so pale as to be almost invisible, and it would be preferable to the infusion of galls in this respect, that it produces its effect immediately, and may be confined to those letters only for which such assistance is wanted.

In the "Monthly Review" of the volume of *Transactions* above cited, the following method is proposed for preventing ink from decaying. It consists in washing over the paper on which the writing is to be made with the colouring matter of Prussian blue; and by writing upon it afterwards with

common ink, a ground of Prussian blue is formed under every stroke; which will remain strong after the black has been decayed by the weather, or destroyed by acids. The ink will thus bear a larger proportion of vitriol at first, and will have the advantage of appearing blacker when first written.

INK Powder may be prepared, by infusing a pound of galls powdered, and three ounces of pomegranate-peels, in a gallon of soft water for a week, in a gentle heat; and then straining off the fluid through a coarse linen cloth. Add to it eight ounces of vitriol dissolved in a quart of water, and let them remain for a day or two; preparing in the mean time a decoction of logwood, by boiling a pound of the chips in a gallon of water, till one-third be wasted, and then straining the remaining fluid while it is hot. Mix this decoction and the solution of galls and vitriol together, and add five ounces of gum arabic, and then evaporate the mixture over a common fire to about two quarts; when the remainder must be put into a vessel proper for that purpose, and reduced to dryness in *balneo Maria*, i. e. by hanging the vessel in boiling water. The remaining mass, after the fluid is wholly exhaled, must be well powdered; and when it is wanted for use, may be converted into ink by the addition of water.

A portable or extemporaneous ink may be made without galls or vitriol, by mixing half a pound of honey and the yolk of an egg, adding two drams of gum arabic finely levigated, and thickening the whole with lamp-black to the consistence of a stiff paste; which being put to a proper quantity of water, may be used as an ink.

INK, Indian, or Chinese, is an admirable composition, in vain attempted to be imitated in Europe. It is not fluid, like our writing inks, but solid, like our mineral colours, though much lighter. They make it of all figures, but the most usual is rectangular, about a quarter of an inch thick. Some of the sticks are gilt with figures of dragons, birds, flowers, &c. In order to do this, they have little wooden moulds, so curiously wrought, that we could hardly equal them in metals.

To use this ink, there must be a little hollow marble, or other stone, with water in it, on which the stick of ink must be ground, till the water becomes of a sufficient blackness. It makes a very black shining ink; and though it be apt to sink when the paper is thin, yet it never runs or spreads; so that the letters are always smooth, and evenly terminated, how big soever they be. It is of great use in designing, because it may be weakened or diminished to any degree; and there is abundance of things which cannot be represented to the life without it.

From an analysis of this ink, Dr. Lewis concludes that it contains an animal substance soluble in water, and consists of a black powder, mixed with some animal glue. He tried to imitate it, by mixing some lamp-black, prepared from linseed-oil, by hanging a large copper pan over the flame of a lamp to receive its smoke with as much melted glue as gave it sufficient tenacity for being formed into cakes. These cakes, when dry, answered as well as the genuine Indian ink, in regard both to the colour, and the freedom and smoothness of working. Ivory black, and other charcoal blacks, levigated very fine, had the same effect with the lamp-black. It appears from three receipts for the preparation of Indian ink, in Du Halde's *History of China*, that the colouring material is lamp-black, to which is added, in one of them, a quantity of horse-chestnuts, burnt till the smoke ceases. The conglutinating matter, in one of the prescriptions, is a thin size of neat's leather; in another, a solution of gum tragacanth, and in the other, a mixture of size, with a de-

coction of certain vegetables, unknown to us. Du Halde observes, that the Chinese have inks of different goodness and price; that the most essential difference proceeds from the quality of the lamp-black, and that the best is the foot of oil, burnt in lamps, in apartments fitted up for this purpose.

The Chinese have often attempted to use this in their porcelain, to give the colour of black to the figure traced on white vessels, but it has been a vain attempt; for however beautiful and strong the figures might appear when first laid on, and even when the vessels were dried, it all disappeared on the baking, and they came out quite white as they were put in. The colours for this use must be such as can penetrate the varnish, and endure the fire. Mineral colours are found to have these qualities, and these alone therefore are to be employed; such light ones as this black burning off from the surface, and wholly disappearing. *Obs. sur les Coutumes de l'Asie*, p. 329.

INK is also an appellation given to any coloured liquor used in the same manner as black ink; as red, green, blue, yellow, &c. inks. Red writing ink is prepared by infusing a quarter of a pound of the raspings of Brazil wood for two or three days in vinegar; boiling the infusion for an hour over a gentle fire, and afterwards filtering it, while hot, through paper laid in an earthen cullender; then put it again over the fire, and dissolve in it, first, half an ounce of gum arabic, and afterwards alum, and white sugar, of each half an ounce. Red ink may be also made of vermilion, by beating together the glair of four eggs, a tea-spoonful of white sugar, or sugar-candy, powdered, and as much spirit of wine, till they be of the consistence of oil; then adding such a proportion of vermilion as will produce a red colour of sufficient strength; the mixture should be kept in a small phial, or well-stopped ink bottle, and well shook before it be used. Gum-water is often used instead of the glair of eggs; but thin size made of isinglass, with a little honey, is much better for the purpose. Red ink may be made by tempering the solution of copal with red sulphuret of mercury, *e.g.* take of oil of lavender, 120 grains, copal, in powder, 17 grains, and red sulphuret of mercury, 60 grains, dissolve the copal in the oil, and then mix the sulphuret with the solution upon a smooth surface. This, and also the black ink made with copal, possess a permanent colour, and other essential properties of the ink used in printing. The oil of lavender being dissipated with a gentle heat, the colour is left on the paper surrounded with copal, a substance insoluble in water, in spirits, in acids, or in alkaline solutions.

For red printing ink, see PRINTING.

Green ink may be made, by putting an ounce of powdered verdigris to a quart of vinegar, and straining the fluid, after it has stood two or three days: or, instead of this, the crystals of verdigris dissolved in water will answer the purpose; then dissolve in a pint of either of these solutions, five drams of gum arabic, and two drams of white sugar.

Blue ink is made by grinding indigo with honey and the white of eggs, and making it fluid with water.

Yellow ink is made by an infusion of saffron in water, with a little alum and gum arabic: or, by boiling two ounces of Avignon, or French berries, in a quart of water, with half an ounce of alum, till one-third of the fluid be evaporated, and then dissolving in it two drams of gum arabic, and one dram of sugar, and afterwards a dram of powdered alum.

In general, inks of all colours may be made by using a strong decoction of the ingredients used for dyeing, mixed

with a little alum and gum arabic. See the several colour BLUE, GREEN, &c.

INKS, *Sympathetic*, or *Secret*. Every sort of liquor with which a person may write, so that the letters do not appear till there is some particular means used to give them a colour different from that of the paper, is called by the name of *sympathetic ink*; and of this there are a great many kinds described in the writings of Baptista Porta, Lémery, and other authors.

All these inks may be regularly distributed into different classes, according to the different means which are to be used to make them appear; and these are in general the four following. 1. By giving a new liquor, or the vapour of new liquor, a place on the paper, on which the letters are written with the natural invisible ink. 2. By exposing the paper to the air, by which means the letters at first invisible will appear. 3. By passing gently over the letters a matter of some remarkable colour reduced to fine powder. And 4. By exposing the paper to the fire.

This last is by much the best method, and is so general, that it may be prudently used to all papers suspected of containing any secret writing, as it seldom fails to discover it. All the common inks of this kind, however, when they have been once made to appear, either by fire or by any other method, can never be made to disappear again; but there is one kind described by Mr. Hellot, in the Memoirs of the Academy of Sciences at Paris, and since tried many times with us, and elsewhere, which, though the letters it gives are in themselves invisible, and appear like those of some other of these inks, on their being held to the fire, yet they after that will fade and disappear on the paper again, and may be reproduced in this manner several times. This, therefore, is the first known ink of a fifth general class, of which future researches may discover perhaps more.

Of the first class of sympathetic inks, or those which do not appear till the paper on which they are written be made to imbibe another liquor, or the vapour of another liquor, are the following kinds.

To two or three parts of unslaked lime put one of yellow orpiment; powder and mix the two, adding fifteen or sixteen times as much water as there was orpiment; stop up the phial with a cork and bladder, and set it in warm embers; shake the phial now and then for five hours, and warily decant the clear part, or rather filtrate it. In the room of this preparation may be used a saturated solution of common brimstone, made by boiling the brimstone either with quicklime, or in strong alkaline ley. In the mean time, burn a piece of cork thoroughly, and when well inflamed, quench it in common water, or rather in brandy. Being thus reduced into a friable coal, grind it with fair water, wherein gum arabic has been dissolved; and it will make a liquor as black as the common ink.

While these are doing, dissolve, in three times as much distilled or strong vinegar, over warm embers, a quantity of red lead, or of saccharum saturni, in thrice the quantity of water, for three or four hours, or till the liquor have a sweet taste. This liquor will be as clear as common water. Solutions of lead in aquafortis answer the same end, except that, when written with, they are apt to corrode the paper.

The liquors thus prepared, write any thing on paper with this last sort, dry it, and nothing will appear. Over the place, write what you please with the second liquor: it will appear as if written with common ink: when dry, dip a small piece of rag or sponge, in the first liquor, rub it over the written place, and the black writing will vanish; and that wrote with the invisible ink will appear black and legible.

Again, take a book four or five inches thick, and on the first leaf write any thing with the last liquor; turn to the other end of the book, and rub there with a rag, dipt in the first liquor, on that part, as near as you can guess, opposite to the writing, and leave also the rag there, clapping a paper over it; then nimbly shutting the book, strike four or five smart strokes thereon with your hand, and turning the other side uppermost, clap it into a press, or lay it under a good weight for a quarter of an hour, or even half that time; then will the writing done with the invisible ink be found legible there.

The above operation may be varied, by writing the invisible characters with the solution of bismuth in nitrous acid, and exposing them to the vapours of liver of sulphur, or moistening them with a solution of liver of sulphur.

Dissolve white or green vitriol in water, and writing with the solution, nothing will appear. Boil galls in water, and dip a linen rag in the decoction, and with it rub the place before writ, and it will appear black and legible. Rub it over again with spirit of vitriol, or its oil, and the writing will disappear again; rub it over again with oil of tartar per deliquium, the letters will appear again, but of a yellow colour. If the blackness of ordinary ink be destroyed by a sufficient quantity of nitrous acid, the writing made by it will remain invisible till it be moistened with liquid fixed alkali.

The golden sympathetic ink.—This is made by dissolving in aqua regia as much gold as that menstruum can take up, and then adding to the liquor five or six times as much water; in another vessel there must be some tin dissolved in aqua regia; and when that menstruum has also taken up as much of the metal as it can, there is to be added to it an equal quantity of common water. The letters must be written on white paper with the solution of gold, and the writing being dried in the shade, the letters will not appear, at least not for seven or eight hours afterwards; dip a pencil in the solution of tin, and rub that over the solution of gold with which the letters were written, and they will appear of a beautiful purple. It might be supposed, that any other metals which were soluble in the same acid menstruum would equally produce this effect; but experiment shews, that this is not the case; and silver and copper, though both soluble in aquafortis, yet produce no change of colour by these precipitations made by mixing the solutions of them on paper; and this example of such an effect in the solutions of gold and tin, is an exception to the general rules in the solutions of metals, and their effects on one another.

The purple colour of these letters may be again effaced by rubbing some simple aqua regia over the paper, and may be made to appear again by rubbing over that the solution of tin. Kunkel, Cassius and Orschal, with some other writers, made the first steps towards this discovery, by their attempt to give crystal, by means of gold, the colour of the oriental rubies. There are, beside these mineral preparations, some vegetable ones, which give the same phenomena, but these are the more certain.

Of the second kind of sympathetic inks, or those which appear on being exposed only to the air, is the golden ink made by adding to a solution of gold in aqua regia, so much water that the liquor shall not stain a white paper: letters written with this will not appear till the paper has been exposed some hours to the open air, and they will then begin to acquire a colour by degrees, till they at length become of a deep violet colour, tending to black. If, instead of exposing the paper to the air, it be kept in a box close shut up, or closely folded in other paper, it will remain invisible two

or three months; but at the end of that time it will begin to appear, and will by degrees become of a deep violet colour. So long as the gold remains united to its dissolvent, it is yellow; but the acid that dissolves it being of a volatile nature, the greater part of it evaporates, and leaves no more than is just necessary to colour the calx of gold which remains upon the paper.

The second of these is the silver ink, made by a solution of silver in aquafortis, weakened by distilled water, till it will not stain the paper. Letters written with this will be invisible for three or four months, if shut up in a box; but if they be exposed to the sun they become legible in about an hour, because by this means the evaporation of the acid is accelerated. The letters written with this ink are of a slate colour; and that from the sulphureous nature of the aquafortis, every thing that is sulphureous blackening silver. This blackish colour, however, is not permanent; for the sulphureous part finally evaporating, the letters are left to their natural appearance, and are of a fine true silver colour, if the silver that was used was fine, and the place open.

In this class there may also be placed several metallic dissolutions; as that of lead in vinegar, and of copper in aquafortis, which give at length a brownish colour upon the paper; as also the solution of tin in aqua regia, of mercury in aquafortis, of iron in vinegar, of emery and several of the pyrites in spirit of salt. But all these, though they give letters which are after some time legible, on being exposed to the air, are also made to appear instantly on the paper, holding them to the fire. Each of these solutions gives its own particular colour; but they have all this disadvantage, that in time they eat away the paper, and the letters are seen in the shape of so many holes.

Of the third class of ink, or that which appears on rubbing over the paper with a brown or black powder, are almost all the glutinous expressed juices of plants, which are themselves of no remarkable colour, the milk of animals, or any other thick and viscous fluids. To use these, the letters must be written on a white paper, and when dry, there is to be thrown over them the fine powder of any coloured earth, or other such substance; and the writing will afterwards appear coloured, because its viscous quality remains sufficiently in it for the entangling and retaining this fine powder, though it falls easily off from every other part of the paper. Mem. Acad. Science, Par. 1737.

Among the methods which Ovid teaches young women to deceive their guardians, when they write to their lovers, he mentions that of writing with new milk, and of making the writing legible by coal-dust, or foot.

“Tuta quoque est, fallitque oculos, e lacte recenti
Littera: carbonis pulvere tange: leges.”

De Arte Amandi, l. iii. v. 629.

Ausonius proposes the same means to Paulinus, and he afterwards teaches other methods of secret writing. Auson. Epist. xxiii. v. 21, &c. Enneas, in Poliorceticis, cap. 37, and Gellius, lib. xvii. cap. 9, mention the like. Pliny, lib. xxvii. cap. 8. mentions the milky sap of certain plants for a similar purpose.

Of the fourth class, or those inks which become visible on holding them to the fire, there are a vast number; and indeed all infusions, the matter of which is readily burnt to a sort of charcoal by a little fire, will answer this purpose. The nicest of this kind is the sal ammoniac ink, made by dissolving a scruple of sal ammoniac in two ounces of fair water. Letters written with this solution are invisible on the paper, till it is held before the fire, or has an

iron a little heated passed over it. The rationale of this is, that the inflammable part of the sal ammoniac is burnt to charcoal by a heat which is not sufficient to scorch the paper; and this is the case with all the rest of this class. The letters written with this solution are, however, of no great duration; for the salt being apt to moisten in the air, the letters soon spread, and run together in a confused manner.

Dr. Lewis says, that all the salts which he has tried produce this effect in a greater or less degree; nitre, alum, tartar, very weakly; sea-salt more strongly; fixed alkaline salts still more so; but sal ammoniac the strongest of all. Metallic solutions, made in acids, and diluted so as not to corrode the paper, act in the same manner. The juice of lemons and milk have also been used as sympathetic inks, the writing with which appears upon the application of heat sufficient to decompose the oily and mucilaginous parts of these liquors.

The fifth class of sympathetic ink contains only one yet known kind.

This, though in itself invisible, becomes of a blueish green when held to the fire; and this colour disappears again as the paper cools, and is to be produced again on holding it again to the fire: and this for a long time, and a repeated series of trials. It may also, according to the different manner of treating it, be made to appear blue, green, yellow, red, and some other colours. This property of the tinging matter of bismuth ore was published at full length by a German lady, in 1705.

A certain German chemist shewed the academy at Paris a salt of rose-water, which became blue on holding it to the fire, and at the same time shewed the ore from which he procured the salt, which he called an ore of marcasite, a name given by many to the bismuth ore. He added, that this was the mineral from which the fine blue smalt of Sneberg was prepared, and that no other ore but this afforded it, and that he made the tincture from this mineral with aquafortis, which he fixed with sea-salt.

This was the substance of what the German declared, and from what Mr. Hellot, in 1736, took the hint for his discovery of this remarkable ink. The salt was, after many experiments, at length found to be produced from an arsenic ore; and it was found, that all the cobalts and ores of bismuth afford a tincture capable of these changes by fire.

The method of preparing it is this: pour upon two ounces of arsenic ore, grossly powdered, a mixture of five ounces of aquafortis, and five ounces of common water. After the first ebullition is over, place the vessel in a gentle sand-heat, and let it stand there till no more air-bubbles seem to ascend; after this increase the fire, so as to make the liquor boil for about a quarter of an hour; after this the liquor will become of a reddish colour, and when cold it is to be decanted clear off from this sediment into a phial; and after standing in that some time, it is to be again decanted off from what is precipitated there; and so on for three or four times till it is quite clear; for it must not be filtered, lest the acid should take something from the paper that might spoil the effects. When the liquor is clear, there must be added to it two ounces of white sea-salt: this mixture is to be evaporated over a gentle sand-heat, till there remains only a dry saline mass. When the liquor is grown hot, it changes from its orange colour to a fair red; and when the aqueous humidity is evaporated, it becomes of a beautiful emerald colour, and from this, as it dries up, it changes by degrees to a dirty green, like that of verdigris in the cake. As it becomes nearly dry,

it must be stirred about with a glass rod or pestle, to keep it from uniting into a mass; and it must not be kept over the fire till perfectly dry, because by that means the colour is often lost, and the salt from green becomes of a dusky yellow; but if it be taken from the fire while it is green, it gradually becomes reddish as it cools, and finally is of a rose-colour. The manner of using this sympathetic ink is this: write with it on a fine and smooth paper, or draw with a black-lead pencil the figure of a plant or tree on the paper; then trace over the same lines with this liquor; let it dry in the open air, and then rub off the black lines with bread, and the paper will appear altogether fair, though the lines made by the ink are in reality sunk deep into it. On holding this paper to the fire the lines will all appear, and the figure of the plant or the letters will be painted in a beautiful blueish green, which will continue so long as the paper is warm; but when it is cold again, they will wholly disappear. The lines, therefore, disappear much sooner in winter than in summer; and in very hot weather it is often necessary to lay the paper on a marble, or other very cold body, in order to produce this effect. At any time, if the paper be scorched in the experiment, the colour of the lines will not disappear again, even if ice be laid upon them. If the writing be exposed for three or four days to a humid air, the lines will appear of a fine pale red. If the impregnation of the ore of bismuth, instead of sea-salt, have alum added to it, and the whole process be continued as before described; and if letters be written with the red liquor as it is taken out of the vessel, the letters will not appear even on holding it to the fire; but if the paper be wetted over with a clear solution of marine salt, and then left to dry, and afterwards held to the fire, the letters will appear blue: The same also will be the effect, if the writing be exposed to the vapour of hot spirit of salt. When this preparation is thus made with alum, instead of common salt, the liquor never becomes green, but continues red, and never changes colour in the drying, or afterwards. The green colour seems to be wholly the effect of the sea-salt; for not only this aluminate impregnation, but others in which other salts had been employed, were always found to be of a different colour.

Glauber's salt, used instead of common sea-salt, left the mass red in the same manner as alum did. Nitre added, instead of sea-salt, gave the precipitate or dried salt a beautiful purple colour, which became white on the instant that water was poured upon it, and a rose-coloured tincture was drawn from it, which gave lines or letters on paper, which continued invisible as long as they were cold, but assumed a beautiful red on holding the paper to the fire; which colour they retained no longer than while the paper continued warm, disappearing afterwards in the same manner with the green colours made by the sea-salt; and if a simple solution of sea-salt be rubbed over the paper, and suffered to dry, and the paper be afterwards heated, the lines appear blue. Borax has the same effect in this preparation with the nitre. All these experiments were made with the neutral salts; but in order to try what would be the effects of alkalies in the mixture, Mr. Hellot added to three ounces of the impregnation of the ore in aquafortis, pure salt of tartar, till the ebullition ceased; but the consequence of this was no great precipitation, but merely the subsiding of a small white sediment; this mixture being evaporated nearly to a dryness, the remaining mass, so long as it was warm, appeared of a beautiful purple; but this became paler as it dried, and turned white in an instant on pour-

ing water upon it. This dissolved in water, in the manner of the others, gave lines on paper of a faint rose-colour, which appeared or disappeared in the manner of those made by the other solutions, according as the paper was hot or cold; and the wetting of the paper with a solution of sea-salt, had the same effects on this as on the others, making the lines appear blue on holding to the fire. Mem. Acad. Par. 1737. See *Colours from METALS*.

The ink may be easily made by digesting zaffre, commonly sold by druggists, in aqua regia; and thus is obtained the soluble part of zaffre, which is the calx of cobalt. This solution is then to be diluted with a little common water. In exposing the paper written with this solution to the fire, care must be taken not to heat it too

much; for in this case, the writing will not again disappear by exposure to cold. This ink, says Macquer, the author of the Chemical Dictionary, may be applied to the drawing of landscapes, in which the earth and trees destitute of verdure, being drawn with common ink, give a prospect of winter; and which may be made to assume the appearance of spring, by exposure to a gentle heat, which covers the trees with leaves and the earth with grass, by rendering visible those parts of the landscapes which are drawn with this sympathetic ink; and, as the solution of regulus of cobalt or zaffre in spirit of nitre acquires a reddish colour by the application of heat, the red solution might be contrived to represent the fruits and flowers.

Joinery

JOINERY is a branch in *Civil Architecture*, and consists of the art of framing or joining wood together, for internal and external finishings of houses; as the coverings and linings of rough walls, or the coverings of rough timbers, and of the construction of doors, windows, and stairs.

Hence joinery requires much more accurate and nice workmanship than carpentry, which consists only of rough timbers, used in supporting the various parts of an edifice: joinery is therefore used by way of decoration only, and being always near to the eye, and consequently liable to inspection, requires that the joints should be fitted together with the utmost care, and the surfaces made smooth.

The wood used is called stuff, and is previously formed by the pit-saw into rectangular prisms, which are denominated boards, battens, or planks, according to their breadth. Battens run from two to seven inches wide, boards from seven to nine inches wide, and planks from nine inches to any greater breadth that can be cut out of a piece of wood.

The operations of joinery consist of forming surfaces of various kinds, also of grooving, rebating, and moulding, and of mortising and tenoning, and lastly, of joining two or several pieces together, so as to form a frame or solid mass.

Surfaces, in joinery, are either plane or curved, but most frequently plane.

All kinds of surfaces are first formed in the rough, and finally brought to exact forms by means of tools adapted thereto.

Grooving consists in taking away a part of a rectangular section from a piece of wood, so as to form a channel of

equal breadth throughout, with three surfaces, one being parallel, and the other two perpendicular to the surface of the wood from which the channel is recessed: the channel thus formed is called a groove.

Rebating consists in taking away a part from a piece of wood of a rectangular section, so as to leave only two sides, each of a parallel breadth, the one side being perpendicular to the surface of the wood, and the other parallel thereto: the cavity thus formed is called a rebate. From this definition it is manifest, that a rebate can only be formed by reducing the piece of wood to be rebated at the angle itself, and may therefore be looked upon as a half groove.

A mortise is a cavity recessed within the surface of a piece of wood, with four sides perpendicular to that surface, and likewise to each other: the act of making a mortise is called mortising.

A tenon is a projection formed on the end of a piece of wood with four plane sides, at right angles to each other, and to a plane, from which it projects; and this plane is called the shoulder of the tenon.

In the following, all pieces of wood whatever are supposed to be rectangular prisms, and the length in a direction of the fibres; two of the sides of every mortise to be perpendicular, and the other two sides parallel to the fibres; the four sides of every tenon in the direction of the fibres, unless otherwise asserted: likewise, if two of the surfaces of a piece of wood be of greater breadth than the other two, these are called the edges and those the sides, and each line of concurrence, formed by two adjacent sides, is called an arris.

Moulding consists in forming the surface of a piece by curve or plane surfaces, or by both, in such a manner, that

all parallel sections will be similar figures, that is, their boundaries may be made all to coincide.

The first thing to be done in joinery is to select the stuff or boards, which ought to be well seasoned for every purpose in joinery, and then line it out; and if the stuff is not already at the size, as is most frequently the case, it must be ripped out with the ripping saw, or cross cut with the hand saw, or both, as may be wanted. The next thing is the planing of the stuff first upon a side, then the edge squared, and then gaged to a breadth and thickness, should either or both be found necessary.

Two or more pieces of stuff may be fastened together in various ways by pins of wood or by nails, but in work prepared by the joiner for the use of building, pieces are more frequently joined together by making their surfaces coincide, and then plastering them over with a hot tenacious liquid called glue, then rubbing the surfaces until the glue has been almost rubbed out, and the one piece brought to its situation with respect to the other. The best work is always joined by this method.

When boards are required of a greater breadth than common, several common boards must be fastened together edge to edge, either by nailing them to pieces extending across the breadth, or gluing them edge to edge, or by joining pieces transversely together with small boards, tongued and grooved into the interstices.

Two pieces of stuff are joined together at right or oblique angles by mortise and tenon adapted to each other, and fastened together with glue. When a frame, consisting of several pieces, is required, the mortises and tenons are fitted together, and the joints glued all at one time, then entered to their places, and forced together by means of an instrument called a cramp.

The operation of forming a given surface, by taking away the superfluous wood, is called planing, and the tools themselves planes.

The first tools used by joiners are bench planes, which generally consist of a jack plane, for taking away the rough of the saw and the superfluous wood, only leaving so much as is sufficient to smooth the surface; the trying plane to smooth or reduce the ridges left by the jack plane, and to straighten or regulate the surface, whether it be plane or convex; the long plane when the surface is required to be very straight; and the smoothing plane in smoothing, as its name implies, and giving the last finish to the work.

Besides the bench planes there are others for forming any kind of prismatic surfaces whatever, as rebating planes, grooving planes, and moulding planes: but for a more particular description of these and the bench planes, we shall refer to the article PLANE.

The tools employed in boring cylindric holes are a stock with bits of various descriptions and sizes, gimblets and Brad awls of several diameters.

The tools used in paring the wood obliquely, or across the fibres, and for cutting rectangular prismatic cavities, are in general denominated chisels: those for paring the wood across the fibres are called firmers, or paring chisels; and those for cutting rectangular prismatic cavities, are called mortise chisels, the rectangular cavities themselves being called mortises when made to receive a projection of the same form and size, and by this means to fasten two pieces of wood together at any angle. The sides of all chisels, in a direction of their length, are straight, and the side of a chisel which contains the cutting edge at the end is steel. The best paring chisels are made entirely of cast steel. Chisels for paring concave surfaces are denominated gouges.

Dividing wood, by cutting away a very thin portion of the material of equal thickness throughout, to any required extent, by means of a thin plate of steel with a toothed edge, is called sawing, and the instruments themselves are called saws, which are of several kinds, as the ripping saw, for dividing boards into separate pieces in a direction of the fibres; the hand saw, for cross cutting and sawing thin pieces in a direction of the grain; the panel saw, either for cross cutting or cutting very thin boards longitudinally; the tenon saw, with a thick iron back, for making an incision of any depth below the surface of the wood, and for cutting pieces entirely through, not exceeding the breadth of that part of the plate without the iron back; likewise a fash saw and a dovetail saw, used much in the same way as the tenon saw. From the thinness of the plates of these three last saws, it is necessary to stiffen them by a strong piece of metal called the back, which is grooved to receive the upper edge of the plate that is fixed to the back, and which is thereby secured and prevented from buckling. When it is required to divide boards into curved pieces, a very narrow saw without a back, called a compass saw, is used, and in cutting a very small hole a saw of a similar description, called a key-hole saw, is employed. All these saws have their plates longer and thinner, and their teeth finer, as they succeed each other in the order here mentioned, excepting the two last, which have thicker plates and coarser teeth than either the fash or dovetail saw. The external and internal angles of the teeth of all saws are generally formed at an angle of 60 degrees, and the front edge teeth slope backward in a small degree, but incline or recline from the straight line drawn from the interior angle perpendicular to the edge in the plane of the plate, as the saw may be employed in ripping or in cross cutting, or cutting perpendicular to the fibres. The teeth of all saws, except turning and key-hole saws, are bent on contrary sides of the plate, each two teeth succeeding each other, being alike bent on the different sides of the plate; viz. the one as much to the one side as the other is to the other side, and consequently all the teeth on the same side alike bent throughout the length of the plate for the purpose of clearing the sides of the cut which it makes in the wood.

Of all cutting tools whatever, the saw is the most useful to the joiner, as the timber or wood which he employs can be divided into slips or bars of any size, with no more waste of stuff than a slice, the breadth of which is equal to the depth of the piece to be cut through, and the thickness equal to the distance of the teeth between their extreme points on the alternate sides of the saw measured on a line perpendicular to the said sides: whereas, without the use of the saw, cylindrical trees could only be reduced to the intended size by means of the axe; in the use of which there would not only be an immense consumption of stuff, but also much greater labour would be required to straighten it.

Joiners use a small axe, called a hatchet, for cutting off the superfluous wood from the edge of a piece of a board, when the waste is not of sufficient consequence to be sawn.

All the above are what are commonly denominated edge tools, but there are others required to regulate the forms. All angles whatever are formed by other reversed angles of the same number of degrees as an exterior angle by an interior one, and the contrary. The instrument for trying right angles is called a square, and those for trying oblique angles are called bevels. The two sides which form the edge of a square are always stationary, but those of bevels are generally moveable one leg upon the other round a joint.

In some cases, where a great number of pieces are required to be wrought to the same angle, a stationary bevel, called a joint hook, is used.

When it is required to reduce a piece of stuff to a parallel breadth, an instrument called a gage is used for the purpose. The gage consists generally of a square piece with a square mortise, through which a bar at right angles thereto is fitted and made to slide. The bar, which is called the stem, has a sharp point, cutter, or tooth at one extremity, projecting a little from the surface, so that when the side of the gage, next to the end which has the point, is applied upon the vertical surface of the wood, with the flat side of the stem which has the tooth upon the horizontal surface, and pushed and drawn alternately by the workman from and towards him, the cutter will make an incision from the surface into the wood, at a parallel distance from the upper edge of the vertical side on the right hand. This line, so drawn, will mark out with precision, and shew the superfluous stuff to be taken away.

When a mortise is required to be cut in a piece of wood, a gage with two teeth is used. The construction of this instrument is the same as the common gage; but in addition thereto, the stem has a longitudinal slider with a tooth projecting from the end of the slider, so that the two teeth may be brought nearer, or to any remote distance from each other, at pleasure; and also to any distance, from the face of the head or guide within the reach of the stem.

When wood has been planed, and required to be sawn across the fibres, and as it is necessary to be kept stationary while sawing, in order to prevent the sides or the edges from being bruised, joiners use a flat piece of wood with two projecting knobs on the opposite sides, one at each end, called a side hook. The vertical side of the interior angle of one of the knobs is placed close to the vertical side, and the under side upon the top of the bench; then the wood is pressed against the knob which projects from the upper surface while it is cutting with the saw: but the use of two side hooks is better, as they keep the piece of wood to be sawn more steady.

When it is required to cut a piece of wood to a mitre with one side; that is, to half a right angle, joiners use a trunk of wood with three sides, like a box without ends, or a top, the sides and bottom being parallel pieces, and the sides of equal heights: through each of the opposite sides is cut a kerf in a plane, perpendicular to the bottom, at oblique angles of 45 and 135 degrees, with the planes of the sides; and another kerf is made in the same manner, so as to have its plane at right angles to the former. The trunk thus constructed is called a mitre-box. When the wood is to be cut, the mitre-box is fixed steady against two side hooks, and the piece, which is always less than the interior breadth of the mitre-box, is laid within, and pressed against the farther interior angle of the mitre-box with the side downwards, to which the saw-kerf is intended to be perpendicular, and in this position it is to be cut. The two kerfs in the sides of the mitre-box are requisite, in order to form the acute angle on the right or left-hand side of the piece, as may be required.

When it is required to make a piece of wood straight in one direction, joiners use a slip of wood straightened on one edge, from which the slip of wood itself is called a straight edge. Its use is obvious; by its application it will be seen whether there is a coincidence between the straight edge and the surface.

When it is required to know whether the surface of a piece of wood is in the same plane, joiners use two slips of wood straightened each on one edge with the opposite edge

parallel, and both pieces of the same breadth between the parallel edges: each piece has therefore two straight edges. Suppose it were required to know whether a board is twisted or its surface in a plane, the workman lays one of the slips across the one end, and the other across the other end of the board, with one of the straight edges of each upon the surface; then he looks in the longitudinal direction of the board, over the upper edges of the two slips, until his eye and the two upper edges of the slips are in one plane; or otherwise, the intersection of the plane, passing through the eye and the upper edge of the nearest slip, intersect the upper edge of the farther slip. If it happen as in the former case, the ends of the wood under the slips are in the same plane; but should it happen as in the latter, they are not. In this last case the surface is said to wind; and when the surface is so reduced that every two lines are in one plane, it is said to be out of winding, which implies its being an entire plane: from the use of these slips they are denominated winding sticks.

Before we can proceed to the method of bringing a rough surface to a plane, it will first be necessary to shew how to make a straight edge or ruler.

Here the joiner must not lose sight of the definition of a straight line, *viz.* a straight line is that which will always coincide with another straight line, however applied together.

The operation of making the edge of a board straight is called by joiners shooting, and the edge so made is said to be shot.

Straight edges may be thus formed; plane the edges of two boards and apply them together, so that the superficies or faces of the boards be in the same plane, and if there be no cavity between the joint the edges will be straight; but if not, the faces must be applied to each other, the edges brought together, and planed and tried as before, until they are found to coincide.

Another mode is by having a plane surface given: plane the edges of a board as straight as the eye will admit of, and apply the face of it to that of the plane, and by the edge of the board draw a line, turn the board over with the other side upon the plane, and bring the planed edge to the line drawn before, and the extremities of the edges to their former places, and draw another line; then if all the parts of this line coincide with the former line, the edge is already straight, but if not, repeat the operation as often as may be found necessary.

Another mode is to plane the edge of a board as straight as the eye will admit of; then plane the edge of another board until it is made to coincide with the former; take a third board and plane the edge of this in like manner, by making it coincide with the edge of the first board; apply the edges of the two last boards together, then if they coincide the operation is at an end, but if not, repeat it as often as may be found necessary.

By any of the methods now shewn, the superficies of the boards, to be shot, are supposed to be parallel planes not very distant from each other; for if the faces be not parallel, or if the thickness be considerable, the operation will be the more liable to error.

To reduce the rough surface of a body to a plane.—This will not be very difficult, when it is known that a plane is that which will every where coincide with a straight line.

The most practical methods are the following: Let the workman provide two winding sticks, and apply them as before directed, making the ends out of winding if they are not found to be so; then if all the parts of the surface are straight on which the edges of the winding sticks were

placed, it is evident that the whole surface must be plane. If the surface is hollow between the said lines, one of the ends or both must be planed lower, until the surface acquires a small convexity in the length, and then, if straightened between the straight lines at the ends, it will be a perfect plane.

Another mode of forming a plane of the surface is of a quadrilateral form: apply a ruler along the diagonals, then if they are straight they are in a plane, but if they are both hollow, or both round, the surface to be reduced is either concave or convex, and must be straightened in these directions accordingly; and, lastly, if by trying across the diagonals with the straight edge it be found that the one be hollow and the other round, the surface of the board winds. In this case bring down the protuberant part of the convex diagonal, so as to be straight with the two extremities; then straighten the concave diagonal, by planing either of the two ends or both of them, according as the thickness of the board will require. Both diagonals being now straight, traverse the wood, that is, plane it across the fibres, until all the protuberant parts between the diagonals are removed; then the workman may proceed to smooth it by working it in the direction of the fibres.

To join any number of planks together, so as to form a board of a determinate breadth, the fibres of each running longitudinal to those of any other—Shoot the two edges that are to be joined; turn the sides of the boards towards each other, so that the edges that are shot may be both uppermost; spread these edges over with strong glue of a proper consistence, made very hot; one of the boards being fixed, turn the other upon it, so that the two edges may coincide, and that the faces may be both in the same plane; rub the upper one to and fro in the direction of the fibres till the glue is almost out of the joint; let these dry for a few hours; then proceed to make another joint; continue to join as many boards or planks in the same manner, till the whole intended breadth be made out. If the boards or planks of which the board is to be composed are very long, the edges that are to be united would require to be warmed before a fire; and, for rubbing and keeping the joints fair to each other, three men would be found necessary, one at each extremity, and one at the middle. Boards, glued together with this kind of cement, will stand as long as the substance of the deals or planks composing them, if not exposed to rain or intense heat, provided that the wood has been well seasoned beforehand, and that the grain be free and straight, uninterrupted with few or no knots. When a board which is to be exposed to the weather is to be made of several boards or planks, the cement to be used for uniting them should not be of skin glue, but of white lead ground up with linseed-oil, so thin that the colour may be sensibly changed into a whitish cast: this kind of glue will require a much greater time to dry than skin glue. Boards to be exposed to the weather, when their thickness will admit, are frequently tongued together; that is, the edges of both boards are grooved to an equal distance from the faces, and to an equal depth; and a slip of wood is made to fit the cavity made in both: this slip should be made to fill the grooves, but ought not to be so tight as to prevent the joint from being rubbed with proper cement.

To glue any two boards together forming a given angle.—This may either be accomplished by shooting the edge of the one board to the whole of the given angle, and the face of the other straight; then, by applying these two surfaces together, and rubbing as before, they will form the angle required; or, if the two edges are shot to half the given angle, and the edges applied together and rubbed and

let as before, the faces of the boards will form the angle required. In both these methods, when only one side of the board is to be exposed to sight, which is most commonly the case, pieces of wood called blocks are fitted to the angle, and the sides glued across the joint or legs of the angle, being previously planed for that purpose.

To form wooden architraves for apertures by gluing longitudinal pieces together.—Architraves may be formed out of the solid pieces; but as their formation in this way is attended with a waste of both stuff and time, the most eligible method is to glue the parts longitudinally together, as is best adapted to the nature of the mouldings. Architraves of the Grecian form, for doors and windows, generally consist of one or two faces in parallel planes, the one of which recedes only in a small degree from the other, while the outer edge is terminated with one or several mouldings which have a very prominent projection. In this case make a board of sufficient thickness, and in breadth equal to the breadth of the architrave: prepare a slip of wood of a sufficient thickness and breadth for the mouldings on the outer termination of the architrave; glue this slip upon the face close to the edge of the board, with the outer edge flush therewith. In the operation two men will be at least required to rub the slip to a joint with the board; and as it often happens that the side of the slip, which is to comply with the surface of the board, is considerably bent, the slip is nailed down to the board; but, previously, small square pieces of wood, called buttons, are bored with holes, one in each, and a nail is put through the hole to the head; then the slip is also bored with a bradawl; and the nails, with the pieces thus described, are entered and driven home as far as the buttons will permit. The buttons may be about three quarters of an inch thick, and the other two dimensions each equal to, or something more than, the breadth of the slip. The slip is sometimes grooved; and the edge of the board is tongued, glued, and inserted in the groove, instead of the above method. Sometimes, also, the two faces are made of different boards tongued together at their joining; then the whole is afterwards stuck into mouldings.

To form the surface of a cylinder with wood, whose fibres are in planes perpendicular to the axis of the cylinder, such as may be used in circular dado, or the soffits of windows.

Method 1.—When the dimension of the cylindric surface, parallel to the axis, is not broader than a plank or board: this may be done by bending and gluing several veneers together; and the first upon a mould or brackets, the edges of which are in the surface of the proposed cylinder parallel to its axis.

This may be accomplished by means of two sets of brackets fixed upon a board with hollow cylindric space between them, of sufficient thickness for taking in the veneers, and double wedges for confining them. If this operation is carefully done, and the glue properly dried, the wedges may be slackened, and the cylindric part so glued up will be found to stand very well; but it must be observed, that, as the wood has a natural tendency to unbend itself, the curve surface, upon which it is glued, should be somewhat quicker than that intended to be made.

Some workmen take another method by forming a hollow cradle, and bending the veneers into it, and confining their ends with wedges, which compress them together; and by a very small degree of rubbing, with a hammer made for this purpose, the glue will be forced out of the joint.

Another method is to form a cradle or templet to the intended surface, and lay a veneer upon it; then glue blocks

of wood upon the back of it, closely fitted to its surface, and the other joints to each other, the fibres of the blocks corresponding with those of the veneer.

A third method is to make a cradle and place the veneers upon it, confining one end of them spread in the glue between the veneers with a brush, and fix a bridle across, confining the ends of this bridle either by nails or by screws; open the veneers again, and put in glue a second time between each two, and fix another bridle across them: proceed in this manner to the other extremity.

A fourth method is to run a number of equidistant grooves across the back of the board at right angles to its edges, leaving only a small thickness towards the face, let this be bent round a cradle or templet made on purpose; and let the grooves be filled with slips of wood, which, after the glue is quite dry, are to be planed down to the surface of the cylindric board, which may be stiffened with canvas glued across the back.

Instead of using a grooving plane, workmen frequently make kerfs with the saw; but this is not so strong when finished, as it is very difficult to insert the slips, and very uncertain as to the depth of each of the kerfs, which will occasion a very unequal bending of the board, if not to a regular depth.

To bend a board, so as to form the frustum of a cone, or any segmental portion of the frustum of a cone, such as the soffit of the head of an aperture.—Find the form of the covering according to the geometrical principles of carpentry; cut out a board to this form, and run a number of equidistant grooves across it tending to the centre: this being fixed to a templet made to the surface of a cone, proceed and finish it in the same manner as in the last method shewn for a cylinder.

To bend boards so as to form a spheric surface.—Make a mould to the covering of a given portion of the sphere in plano, according to the geometrical principles of carpentry; complete the number of staves by this mould; make a templet or mould to a great circle of the sphere; groove each of the staves across at right angles to a line passing through the middle, and bend it round the templet; put slips in the grooves; lastly, shoot the edges of the staves, so as to be in planes tending to the centre of the sphere: these staves being glued together will form a spheric surface.

To glue up the shaft of a column—Describe two circles of diameters, equal to those of the superior and inferior ends of the shaft.

Circumscribe these by polygons, consisting of the same number of regular sides as the column is to consist of staves.

From the angles draw lines to the centre, which will give the bevells for working the edges of the staves. In this process, after two pieces are glued together, and dried, proceed to glue a third piece in the same manner and so on to the last but one. The last, previous to being glued, the blocks should be fixed upon it, and then the whole may be closed in. N. B. The number of staves should be eight or twelve, otherwise the joint will fall in the middle of the flutes, which should not be in the case. It is a very good method to diminish the staves, previous to their being glued together, as otherwise the waste of stuff would be very great.

To glue up the base of a column in several horizontal courses, or rings, in order to be turned in a lathe.—Consider the number of horizontal or bevel joints, which are best made at the internal angles of mouldings; prepare a board, so as to have a plain surface; let a circle be described on the plane of a

diameter, equal to the diameter of the greatest circle in the height of the course, and circumscribe an equilateral polygon about the circle, with as many sides as there are to be pieces in a course, and from the angles draw lines towards the centre: then any radial line, and one of the adjoining sides of the polygon, will form the angle by which the ends of every two pieces that are to form the course will meet, so as to make their planes coincide. The geometrical part being thus finished, prepare the pieces each in length equal to the side of the polygon, with an acute angle at each end from the outer side, equal to the afore said angle on the board, so that each piece will thus have a longer and a shorter side: apply the longer side of each piece to the polygon, the shorter side being next to the centre, so that one of the ends may coincide with a radial; then the other end will also coincide, and thus the whole will meet together, if the work be true. But as this is difficult, it is common to allow the pieces to be a small matter longer, in order to plane them, so as to make close work: for though the methods be true, the workman, though ever so careful, cannot work to geometrical exactness; even the thickness of shaving, or the smallest degree of twist in the board, will spoil the work. Suppose the course completely jointed; take the whole to pieces, and glue the surfaces which are to meet each other, and rub each two adjacent pieces to a joint, until the whole ring or course is firmly closed. When the glue is dry, plane the upper side truly; take the radius of the greatest projecting member in the next course, and describe a circle upon the top of the course, on the same axis with the centre of the lower circle; and with the centre of this circle, in the plane of the top of the course, bisect any one of the arcs comprehended between two adjacent joints; and from the point of bisection, divide the circumference into as many equal parts as there are pieces in the under course, and draw radiating lines towards the centre: join every two nearest points in the circumference, and thus an inscribed polygon will be formed; draw lines to touch the circumference parallel to the sides of the inscribed polygon, and thus a polygon will be made to circumscribe the circle: produce the radiating lines, until they meet the angles of the circumscribing polygon; then the sides of the circumscribing polygon will be the situations of the bottom edge of the vertical outer sides of the second course, and the radiations the situations of the joints. Proceed, as in the first course, to adapt the pieces to their respective situations, making close work: glue each piece to its place on the lower course, and likewise the joints; and when the glue of this course is dry, its upper side may be planed true. Proceed with the uppermost course in the like manner, making the joints fall in the middle of the lengths of the pieces of the lower course; and when finished, the work may be sent to the turner.

To glue up the Ionic and Corinthian capitals for carving—The abacus must be glued in parts, such that their joints may be in vertical planes. The leaves and caulicoles of the Corinthian capital may be first made of rectangular blocks, and fixed to the vans.

To make a cornice round a cylindric body out of the least quantity of wood, when the body is greater than a half cylinder, and concave, and when the members will nearly touch a right line applied transversely.—Draw a section of the cylinder through its axis, and let the section of the cornice be represented upon the cylindric section. Draw a transverse line touching the two extreme members of the cornice: parallel to this line draw another line within, at such a distance from the former as may be found necessary for thickness of stuff; produce this last line, until it meet the line representing the

axis of the cylinder. The junction will either be above or below, according as the cornice is applied to the convex or concave sides of the cylinder. This meeting is the centre of two concentric circles, whose radii are the distances between the nearest and farthest extremes of the section of the cornice. This is evidently an application of the method of finding the covering of a cone. When mouldings are got out in this manner, *viz.* by a piece which does not occupy the space, when set to the place represented by the height and breadth, they are said to be sprung.

When a cornice is to have much projection, the corona or middle part is got out of a solid piece, and the parts above and below, or one of them, as may be found necessary, only set to the spring, and supported by brackets.

To describe the various kinds of joinings in the practice of joinery.—*Fig. 1. Plate XXII.* is a section shewing the most simple method of joining boards, or any kind of framed work together at the angles; this kind of joining is much used in coarse work; it is called lap-joining.

Fig. 2. the method of joining troughs together.

Fig. 3. the method of joining dado together at an internal angle.

Fig. 4. the manner of fixing two pieces of framing together at the angle of their meeting with a returned bead, in order that the joint should be concealed. This is only used in common finishings; in good finishings a bead of this of an inch broad is generally run close to the joint, and the angle is left entire.

Fig. 5. shews the common method of mitring. This form is always used in mouldings at an external angle, and sometimes also in internal angles: but for internal angles, scribing is to be preferred, when it can be applied, which may always be the case, when there are no quirked mouldings; that is, when mouldings are such that a perpendicular line to the plane of the wall may fall upon any part of them without going through the solid of the moulding.

Fig. 6. is another method of mitring. This may be used in all plane surfaces, at an external angle, but is not applicable to mouldings. This manner of mitring is much more preferable in point of strength to that of *fig. 5*, in cases where the two can be applied.

Dove-tailing is another mode of joining two plane surfaces together at an angle, by cutting pins of a prismatic form and trapezoidal section on the end of one piece, and notching the end of the other in the same manner, so that the exterior parts of the one is adapted to the indentations of the other, without leaving any cavity when the two sides are brought home to their places. This is the strongest method of joining plane boards; it should always be used in work which may be required to be moved from place to place. There are three sorts of dove-tailing. One kind, called common dove-tailing, shews the ends of the joints: another kind, called lap-dove-tailing, conceals the joints of the dove-tails, but shews a straight joint, not at the angle, but at a small distance parallel to it. The third sort is called mitre dove-tailing, which shews no joint but in the angle. This method is very neat, it is stronger than the straight joint shewn by the section *fig. 6*, and where both strength and beauty is required it may be preferred to any other. *Fig. 7, N 1.* is a section of common dove-tailing; *N 2.* the side of one of the pieces shewing the pins; *N 3.* shews the ends of the pins; *N 4.* the side of the other piece, shewing the indentations for receiving the pins.

Fig. 8. N 1, 2, 3, 4, and 5, different parts of mitre dove-tailing.

To join two pieces of wood together, the fibres of the one run-

ning transversely to the fibres of the other by mortise and tenon or dove-tailing.—One method is by cutting a mortise to a very small depth in the one piece, and a tenon of the same length in the other, and by bolting them together with one or two bolts: where the breadth of the piece having the tenon is considerable, the nuts are to be let in from that side of the tenoned piece which is not exposed to sight; the heads of the bolts upon the mortised piece may be sunk into the wood entirely below the surface, and the cavity may be filled up with a piece of the same kind of wood, neatly fitted in.

Definitions.—1. A frame, in joinery, is the connection of several pieces of timber of an equal thickness, joined transversely to each other, made fast by means of mortises and tenons, leaving rectangular spaces between for other pieces of timber, called pannels, each of which is inserted into each edge of the former by means of a groove.

2. Those parts of the frame which terminate the two vertical extremes are called styles.

3. The horizontal parts, which are mortised into the styles, are called rails.

4. If there be any intermediate pieces mortised into the rails, parallel to the styles, such pieces are called muntons.

In framed-work, rails have several epithets, according to their situations; that bordering the framing at the lower extremity is called the bottom rail, that bordering the framing, at the other extremity, is called the top rail. The names of intermediate rails vary according to their number and situation. In doors, that in which the lock is inserted is called the middle, or lock rail; the intermediate rail next to the top rail, is called the frieze rail.

Doors.—A door, in joinery, is a framed piece of timber-work, or boards nailed together, for the purpose of shutting up at pleasure any aperture in a wall or partition, in order to give or prevent passage from one apartment to another.

Plate XXIII. fig. 1. is a four equal-pannelled door: the form is only used in very common work, and is frequently without mouldings.

Fig. 2. is a nine-pannelled door, with square pannels at the top. This form is frequently used in street-doors, of which the back is often lined with boards, in the manner of *fig. 3*, flush with the styles and top rail; the other rails and muntons must therefore be recessed upon one side to receive the boarding.

Fig. 4. is a six equal-pannelled pair of folding-doors, having two pannels in the breadth.

Fig. 5. is a double margin, or a pair of folding-doors, with four pannels in height, and two in breadth, having lying pannels below the top-rail, and above the lock-rail.

Fig. 6. is a ten-pannelled pair of folding-doors, five in height, and two in breadth, having lying pannels at the top, bottom, and in the middle, with long pannels between them. Of this form is the ancient door of the Pantheon at Rome.

Fig. 7. a sash-door: this form, if not shut with another separate door, should have shifting-shutters, to cover the glass parts, fixed with bolts and nuts. For this purpose, it should at least be one inch and a quarter thicker than a pannelled door in the same place: this gives room for the outside of the shutter to be flush with the styles of the door; but if otherwise, an ugly frame must be patched round the glazed parts, in order to contain the shutter.

Fig. 8. an ancient door, of which form are the windows and door of the temple of Vesta at Rome, and also those of the temple of Eretheus at Athens.

Figs. 9 and 10. are doors of communication, or such as, when open, will not encumber the floor, as other kinds of recessed doors, by jetting into the room, but may either be

concealed entirely within the partition, or folded close to it : they are used for the purpose of making a free communication between one room and another, at great meetings or balls, when any one of the rooms would be insufficient though large enough for common use.

Fig. 9. the elevation of a door to be folded close to the partition, by means of a hanging stile, or pilaster, on each side which is first hung to the jamb, then a folding door to each pilaster.

Fig. 10. is a door consisting of four parts : each middle part is hinged to each extreme part ; each two parts, on each side, in time of company, may be removed entirely

out of the way into hollows on each side of the partition, and guided by grooves at the top and bottom, and made to slide freely upon rollers.

Fig. 11. is a jib-door, that is, such a door as, when shut, may be as much concealed as possible from having the appearance of a door. Jib-doors are used, when only one aperture at the end of the side of a room is necessary ; and when it is required to keep the symmetry of that side, without having the appearance of a door ; the base, surbase, and paper are, therefore, continued over it as in the other parts of the room, the joint being only seen at the top, and upon the edge opposite the hinge.

Iron

IRON, *Eisen*, Germ. *Fer*, Fr. *Ferrum*, Lat. *Ferro*, Ital. *Jeren*, Swed. *Jernet*, Dan. *Vas*, Hung. *Hierro*, Span. *Julazo*, Russ. *Ferro*, Port. Σιδηρο, Gr. *Ἰσχυρ* (*Bharkel*, or *Varzel*), Heb. *Mars*, Alchem.

The use of this metal is of very high antiquity, though not so remote, there is reason to believe, as that of either gold, silver, or copper. The inferior brilliancy of its colour may, perhaps, in some degree, account for this circumstance; as well as the greater skill required to obtain it from its ore, and convert it to the purposes of art. It is mentioned frequently in the pentateuch; and was, in the time of the celebrated writer of that history, employed for the fabrication of swords, knives, and various other sharp-edged instruments. We may form some estimate of the value that was then attached to it, from an expression in the eighth chapter of Deuteronomy, where Moses tells the Israelites, in his descriptive eulogy of the Land of Promise, that it is "a land whose stones are iron, and out of whose hills" they may "dig brass." A circumstance, illustrative of the same fact, at a later date, is furnished about 400 years subsequent to that period, when Achilles proposed a ball of iron as one of the prizes to be distributed to the victors at the games instituted in honour of Patroclus. (Ιλίουπύρρον, Ψ.) The art of working it appears, in the course of a few succeeding centuries, to have arrived at considerable perfection; for, according to the information of Herodotus (Clio xxv.), a saucer of the metal, very curiously inlaid, was presented by Alyattes, king of Lydia, to the Delphic oracle, which, he says, "is of surprising workmanship, and as worthy of observation as any of the offerings preserved at Delphi." The durability of iron, and its indispensable assistance in the preparation of every other metal, make it one of the most valuable possessions that has been bequeathed to the use of civilized man. "Without it," observes Fourcroy, "agriculture could not have existed, nor could the plough have rendered the earth fertile. The philosopher, while he studies the progress of the human understanding, and compares the fortune and state of the different nations established

on various portions of the surface of the globe, will remark, that their iron-works seem, in some measure, to be proportioned to their intelligence, to the advancement of reason amongst them, and the degree of perfection to which the arts have arrived. When we consider it in this point of view, as the agent by which men, in the variety of its uses, and the numerous wants it supplies, acquire enjoyments which would be unknown to them if they did not possess these products of their industry, iron must singularly contribute to extend their ideas, to multiply their knowledge, and to conduct their spirit towards that perfectibility, which nature has given no less, as the character of the human species, than as the source of all the advantages it can enjoy." Syft. vol. 6.

Iron is a malleable and ductile metal, of a blueish-white colour; is susceptible of a very high polish, and of the specific gravity, according to the tables of Muschenbroeck, Swedenburg, and Brisslon, of from 7.600 to 7.895, and even 8.166. It is soluble in most acids, and precipitable from its combination with them, by various re-agents, which will be hereafter pointed out. With the Prussic acid it forms that beautiful pigment known in commerce, and the arts, by the name of *Prussian blue*; and in a variety of other ways, constitutes the basis of many valuable preparations. The combinations under which it is exhibited to us in nature are detailed in the following section.

§ 1. Ores of Iron.

Sp. 1. *Native iron*. *Gediegen-eisen*. *Fer natif*. *Ferrum nativum*.

Its colour is steel-grey, passing to silver-white. Occurs only in a ramose form; the masses alluded to by Brochant and others being now considered of meteoric origin. Surface glistening. Internally it is intermediate between glistening and glimmering; and its lustre metallic. Fracture hackly. It is rather soft, is completely malleable, and flexible without being elastic. Sp. gr. 7.8.

A specimen from a mine near Kamfdorf, in Saxony, yielded, according to Klaproth,

Iron	92.5
Lead	6.0
Copper	1.5
	<hr/>
	100.0

The varieties which contain nickel are meteoric.

It is found in detached masses, which are usually covered with an oxyd of a brownish colour.

The places of its occurrence are Kamfdorf and Eibens-Stock, in Saxony; Oulle, near Grenoble, in France; and some others.

Sp. 2. *Iron Pyrites. Schwefelkies. La Pyrite Sulfureuse. Ferrum Mineralisatum Pyrites.*

This very abundant mineral is divided by Werner into five subspecies, common, radiated, capillary, hepatic, and cellular.

Subsp. 1. *Common Pyrites.*—Colour bronze-yellow, passing sometimes to gold-yellow. Occurs massive and disseminated. It is very frequently also crystallized. Its forms are the cube, either perfect or truncated, the octahedron, dodecahedron, and sometimes, though very rarely, the icosa-hedron. The crystals are in general small; except the cube, which is middle-sized. Their surface is either smooth or streaked, and varies from glimmering to splendid. Internally it is shining or glistering; and its lustre metallic. Fracture even; sometimes conchoidal. It is hard, brittle, rather easily frangible, and heavy. Sp. gr. from 4.600 to 4.831.

Exposed to the blow-pipe, it exhales a strong odour of sulphur, and burns with a blueish flame. It afterwards passes into a globule, obedient to the magnet, of a brownish colour; and treated with glass of borax, communicates to it a tint of a dark dirty green. It appears to be composed of about 52.5 sulphur, and 47.5 iron.

Its occurrence is almost universal, both with reference to geographic arrangement, and the mineral formations in which it is presented.

Subsp. 2. *Radiated Pyrites.*—Colour bronze-yellow, of a paler hue than the preceding; passing sometimes to brass-yellow. Surface tarnished. Is found massive and reniform, also uniform, globular, and crystallized. The shape of its crystals is cubic, and octahedral; the latter being sometimes truncated on the angles. The external lustre varies between splendid and glistering. Internally it is glistering and glimmering. Fracture usually radiated; sometimes uneven and fibrous. Fragments uniform. Occurs in coarse and large-grained distinct concretions, also lamellated and columnar. It is hard, brittle, very easily frangible, and heavy, but less so than the foregoing subspecies. Emits a sulphureous odour when struck, or rubbed. Sp. gr. from 4.698 to 4.775.

Before the blow-pipe it exhibits the same appearances as common pyrites, and is constituted of about 54 parts of sulphur, and 46 of iron.

It is considerably rarer than the preceding, and is found in veins, particularly those which contain lead or silver.

The places of its occurrence are, amongst others, Cornwall and Derbyshire, in England; Arendal, in Norway; and in various districts of Suabia, Saxony, and Bohemia.

Subsp. 3. *Capillary Pyrites.*—Colour bronze-yellow, inclining more or less to steel-grey. Occurs in very fine capillary crystals. Lustre shining or glistering; metallic. Brittle, and in a small degree flexible. The smallness of its

crystals prevents a more particular account being given of its character.

Its chemical properties are the same as those of common pyrites.

It is never met with but in very small quantity, and is the most rare of all the varieties of pyritic iron. It is most usually accompanied with quartz, lead-glance, or galena, and fluor and calcareous spar.

Is found at Annaberg, Schneeberg, and Johanngeorgenstadt, in Saxony; at Andreasberg, in the Hartz; and other places on the continent of Europe. The capillary pyrites, according to Klaproth's analysis, is not an iron-ore, but nickel, mixed with a small portion of cobalt and arsenic.

Subsp. 4. *Hepatic Pyrites.*—Its colour is intermediate between bronze-yellow and steel-grey, passing sometimes entirely to the latter. On exposure, the fresh fracture changes to a brown. It is found massive, and under a variety of other forms, as stalactitic, cellular, &c. also crystallized. The shape of its crystalline arrangement is prismatic, pyramidal, and tabular, each with six sides. Lustre glimmering, inclining to glistering; metallic. Fracture even, passing sometimes to uneven and imperfectly conchoidal. Fragments indeterminate, sharp-edged. Hard, rather inclining to soft, brittle, easily frangible, and heavy.

This subspecies is said to contain arsenic. It decomposes very easily on exposure to air, which renders it very difficult to be retained in mineralogical collections.

It occurs only in veins, and in those principally which contain red silver ore, galena, blende, common pyrites, and sparry iron-stone. The earthy minerals that accompany it are, for the most part, quartz, sulphat of baryt, and calcareous and fluor spar.

It is found in Derbyshire; at Joachimsthal in Bohemia; Annaberg and Freyberg in Saxony; and in various parts of Sweden, Norway, and Siberia.

Subsp. 5. *Cellular Pyrites.*—Colour bronze-yellow, a good deal inclining to steel-grey. Tarnishes by exposure, and then becomes of a grey tint. Occurs massive; but its most common appearance is cellular. Cells drusy on the surface. Lustre glistering. Fracture conchoidal. Fragments sharp-edged, indeterminate. Brittle, and in a slight degree flexible.

Its occurrence is in veins, where it is accompanied, according to the statement of professor Jamieson, with hepatic and common pyrites, lead-glance, sparry iron-stone, nickel, iron-ochre, brown-spar, heavy-spar, fluor-spar, and quartz.

Is found at Johanngeorgenstadt, in the electorate of Saxony.

Sp. 3. *Magnetic Pyrites. Magnethies. La Pyrite magnetique. Ferrum mineralisatum magnetico pyritaceum.*

Colour copper-red, inclining much to bronze-yellow, and even to pinchbeck-brown. Tarnishes on exposure, becoming then brown. Occurs massive and disseminated; has never been found under any other form. Internal lustre glistering, or shining; metallic. Fracture uneven, and sometimes imperfectly conchoidal: when the latter, it has a lustre bordering on splendid. Fragments indeterminate, rather blunt-edged. Intermediate between hard and semihard. It is brittle, easily frangible, and very heavy. Is attracted by the magnet. Sp. gr. 4.516.

Treated by the blow-pipe, it emits a slight sulphureous odour, and melts with great facility into a greyish-black globule, which is attracted by the magnet, and colours borax black. It is composed of 36.5 sulphur, and 63.5 iron.

It occurs only in the class of rocks denominated primitive; and there only in beds. The minerals which usually

accompany it are galena, magnetic iron-stone, arsenical pyrites and tin-stone; with also quartz, garnet, strahlstein, hornblende, &c.

Its geographic distribution is rather extensive. Amongst many other instances, the following may be enumerated: Moel Elion, in Caernarvonshire, North Wales; Geyer, Breitenbrunn, &c. in Saxony; Bodenmais, in Bavaria; and in different parts of Norway and Siberia.

Sp. 4. *Magnetic Iron-stone. Magneteisenstein. Le fer magnetique. Ferrum magnes.*

Werner divides this into two subspecies; namely, common magnetic iron-stone, and magnetic iron-sand.

Subsp. 1. — *Magnetic Iron-stone.*—Colour iron-black, inclining sometimes to perfect black, and sometimes to steel-grey. Occurs massive, disseminated and crystallized. The form of its crystals is the cube, perfect or truncated; the octahedron, which is also sometimes varied by truncation; the garnet dodecahedron, and the rectangular four-sided prism, terminated by four planes, placed on the lateral edges, as in the hyacinth. These crystals vary much in size. The dodecahedrons and octahedrons have their faces smooth; but the planes of the four-sided prism are transversely streaked. Lustre externally shining; internally varying from glimmering to splendid. Fracture small and fine-grained, uneven, approaching sometimes to small conchoidal, and imperfect foliated. Fragments indeterminate, rather sharp-edged. Occurs sometimes in granular distinct concretions. It is semi-hard, passing to hard; brittle; when in crystals difficultly frangible, and heavy. Sp. gr. 4.200 to 4.939. It is attracted by the magnet; and is itself also magnetic.

Before the blow-pipe it becomes brown, and imparts a dark-green colour to borax. It is supposed to be an oxyd of iron, nearly in a state of complete purity.

This species is very common in primitive mountains, especially in those of gneiss and micaceous schistus. In these situations it arranges itself in beds; but sometimes composes the entire mass of distinct mountains. The *fietsz*, or secondary formations, as they are termed, are not free from it. It occurs in greenstone at Taberg; in hornblende in Smoland, and in basalt near Eisenach. It is usually associated with common hornblende, garnet, and granular limestone. Sometimes with actinote, albest, &c.; but is most frequently found in the vicinity of magnetic pyrites, arsenical and copper pyrites, and common pyrites.

It is found in one of the Shetland isles; in Bohemia, Hungary, Saxony, Italy, France, Switzerland, Siberia, and South America. Is very abundant in Sweden, where it is employed for the manufacture of the iron imported to this country for the supply of the Sheffield market.

Subsp. 2. *Iron-sand.*—Colour deep iron-black, which passes sometimes to ash-grey. Occurs in angular or roundish grains; and also in small octahedral crystals. Surface rough and feebly glimmering. Internal lustre shining, metallic. Fracture perfect conchoidal. Fragments indeterminate, sharp-edged. Streak greyish-black. Semi-hard, brittle, easily frangible, and heavy. Sp. gr. 4.600. Strongly attracted by the magnet.

Its chemical characters are as the foregoing subspecies.

It occurs in the beds of rivers; and also unbedded in the rocks of basalt and wacke.

Is met with in the river Elbe, near Schandau, in Saxony; imbedded in *fietsz*-trap, in Bohemia; and is found also at St. Domingo, Guadaloupe, in Norway, France, the Tyrol, Greenland, &c.

Sp. 5. *Iron-glance. Eisglanz. Le fer speculaire. Ferrum mineralisatum speculare.*

This is also divided into two subspecies; common iron-glance, and micaceous iron-ore, or, as it is called by professor Jameson, iron-mica.

Subsp. 1. *Common Iron-glance.*—Colour steel-grey of greater or less intensity, and sometimes reddish. It occasionally passes into iron-black. Surface very often tarnished, and beautifully iridescent. Occurs massive, disseminated, and crystallized. The form of its crystals is various. The most common is the rhomboidal parallelepipedon; the cube, formed by the truncation of a double three-sided pyramid, and having three triangular faces instead of two of its angles opposite, and octagonal plates bounded by linear trapeziums, six in number, inclined alternately to different sides. Planes of the crystals sometimes smooth, and sometimes streaked. Externally it varies from glimmering to splendid; internally from glistening to splendid; lustre metallic. Fracture compact and foliated. The compact varieties are uneven, and sometimes small conchoidal. The foliated have a fourfold rectangular cleavage. Fragments octahedral or pyramidal; sometimes indeterminate. Edges rather blunt. Generally unseparated. Gives a deep cherry-red streak. It is hard, opaque, brittle, more or less easily frangible, and heavy. Sp. gr. 5.0116 to 5.218. It is magnetic, but less so than the preceding species.

Before the blow-pipe it is infusible, alone; but becomes white when heated on charcoal; and yields a dirty yellow-coloured scoria, with borax. Stated by Kirwan to contain from 60 to 80 per cent. of iron.

This species appears to be confined to primitive, and the class called transition mountains. It has never been found in those of secondary formation. Its occurrence is in beds and veins, where it is usually accompanied with magnetic iron-stone, common pyrites, compact red iron-stone, hornstone, and quartz.

Sweden yields it very abundantly; as also does Norway. Some of the finest specimens are from the isle of Elba, where the ore is said to have been worked for upwards of three thousand years. It occurs in Bohemia, Saxony, Switzerland, France, England (in Lancashire and Cumberland), Hungary, South America, Siberia, &c.

The English specimens occur in cavities in compact red iron-stone. The crystals are usually small; and the lustre of their surface is particularly splendid.

Subsp. 2. *Iron-mica.*—Colour iron-black, passing sometimes to steel-grey, and sometimes to deep-red. The latter is rather the colour of it, when held under the form of thin plates, between the eye and the light. Occurs massive, disseminated, and crystallized. When the latter, it appears in thin tables with six sides. Surface smooth and splendid. Internally it is also splendid, and its lustre metallic. Fracture perfect curved foliated; cleavage simple. Fragments sometimes indeterminate, and sometimes tabular. The massive varieties occur in granular distinct concretions. Thin plates of it are translucent. Its streak is deep cherry-red. It is semi-hard, brittle, very easily frangible, and heavy. Sp. gr. 4.50 to 5.07.

Before the blow-pipe it exhibits the same appearances as the preceding subspecies, except in communicating an olive-green tinge to borax. The proportion of iron which it yields is from 70 to 80 per cent.

It is exclusively confined to primitive mountains, and for the most part to those of a newer formation. It is found, like iron-glance, in beds and veins, and is accompanied with other ores of the metal: calcareous and fluor spar, quartz, hornstone, &c.

Its geographic distribution is rather extensive. It occurs near Dunkeld, in Perthshire; at Dartmoor, in Devonshire;

in one of the Shetland isles; in Norway, Sweden, Russia, France, isle of Elba, and many districts of Germany.

Sp. 6. *Red Iron-stone. Roth-eisen-stein. La mine de fer rouge. Ferrum ochraceum rubrum.*

Werner has divided this into four subspecies, which professor Jameson, in conformity with the principles of the Wernerian nomenclature, has denominated red iron-froth, ochry-red iron-stone, compact red iron-stone, and red hematite.

Subsp. 1. *Red Iron-froth.*—Colour deep cherry-red, sometimes blood-red and brownish-red, and even inclining to steel-grey. Usually friable. Occurs sometimes massive and disseminated; and is composed of scaly parts which soil considerably. Lustre between glimmering and glistening; semi-metallic. Is greasy to the touch, and moderately heavy.

Exposed to the blow-pipe alone, it blackens without melting, and communicates a bright green colour to borax. According to Hauy, it is constituted of

Iron	66.
Oxygen	28.5
Silex	4.25
Alumine	1.25
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	100.

It occurs generally in veins in primitive and transition mountains, accompanied with other ores of iron, copper pyrites, quartz, barytic spar, &c.

Although a rare variety of this metal, it is found rather plentifully in the neighbourhood of Ulverstone, Lancashire, and is also met with in Cornwall. It occurs too in Norway, the Hartz, Saxony, Silesia, Salzburg, Hungary, and South America.

Subsp. 2. *Ochry-red Iron-stone, or Red Ochre.*—Colour varies between blood-red and brownish-red. Occurs sometimes massive and disseminated, sometimes superficial, or coating other ores of the metal, but most usually friable. Lustre faintly glimmering, or dull. Fracture earthy. Fragments indeterminate, blunt-edged. Feels meagre. Soils more or less strongly. Is not very brittle. Easily frangible, and rather heavy. Sp. gr. 2.952.

It is rarely found alone; being generally accompanied with other species of iron-ore, and particularly with compact red iron-stone, and red hematite. It occurs in veins; and is distributed nearly as the two following subspecies.

Subsp. 3. *Compact red Iron-stone.*—Colour between brownish-red and dark steel-grey, passing sometimes to blood-red. Occurs massive, disseminated, and in various imitative forms, as reniform, cellular, &c. It is sometimes found crystallized, and appears either in cubes, or four-sided pyramids, the latter of which are truncated on their summits. The cube is found both perfect and truncated. Surface of the cubes smooth; of the pyramids rough and dull. Internal lustre between glimmering and dull; semi-metallic. Fracture for the most part even. It sometimes, however, passes into coarse-grained, uneven, and large conchoidal. Fragments indeterminate, rather sharp-edged. Streak blood-red. Between hard and semi-hard. Somewhat brittle, and more or less easily frangible, heavy. Sp. gr. 3.423 to 3.76.

It assumes a darker colour before the blow-pipe; but is infusible, even with the assistance of borax. This re-agent, however, is tinged of a yellowish-green by it.

Occurs in beds and veins with red hematite and the pre-

ceding subspecies; and is also accompanied with quartz, red-jasper, and hornstone.

It is found very abundantly in Lancashire; in the Hartz, Saxony, Bohemia, Hesse, Siberia, and France.

It is frequently smelted in this country; and principally in those works which fabricate the variety of iron described in the succeeding part of this article, under the name of *forge-pig*. The richer ores, in fact, are incapable of yielding the most highly carbonized descriptions of iron; partly, perhaps, because they contain too little earthy matter to afford a sufficiently plentiful *cinder*; and partly because their reduction is too immediate.

Subsp. 4. *Red Hematite.*—Colour intermediate between brownish-red and steel-grey; passing sometimes intirely into one or other of them, and even into blood-red. It is from the latter variety that the name of hematite (from *αἷμα, sanguis*,) is derived. Occurs massive and reniform; also stalactitic, globular, uniform, &c. External surface rough and glimmering. Internally glistening, passing into glimmering; lustre semi-metallic. Fracture always fibrous. Fragments usually wedge-shaped; sometimes splintery and indeterminate. In angulo-granular distinct concretions. Streak a bright blood-red. Hard, inclining to semi-hard. Rather difficultly frangible. Brittle, and very heavy. Sp. gr. 4.74 to 5.005.

It exhibits the same chemical characters as the foregoing subspecies, and yields in the large way about 60 per cent. of metal.

According to the recent analysis of M. D'Aubuisson, who has published a very interesting memoir in the 75th volume of the "Annales de Chimie," on the chemical constitution of certain iron ores which appear to have water as an essential ingredient, this mineral is composed of

Peroxyd of iron	-	90
Silex	-	2
Lime	-	1
Volatile matter	-	3
Loss	-	4
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		100

The specific gravity of the specimens here submitted to examination was 4.8. Another specimen, the specific gravity of which was 5.0, yielded the following result:

Peroxyd of iron	-	94
Silex	-	2
Water	-	2
Loss	-	2
<hr/>		
		100

Each of the above presented a trace of manganese, and the latter a similar evidence of lime.

Its geognostic situation is similar to the last.

Lancashire yields it very plentifully, as well as the neighbouring parts of Cumberland. It is found, too, in considerable abundance in Saxony; and in Bohemia, France, Silesia, the Hartz, Siberia, &c.

It is one of the most common varieties of iron ore, and is very frequently employed in the smelting furnace.

Sp. 7. *Brown Iron-stone. Brown Eisen-stein. La mine de fer brune. Ferrum ochraceum brunum.*

This, like the preceding, is divided into four subspecies, which have the same leading distinctions. They consist of brown iron-froth, ochry-brown iron-stone, compact brown iron-stone, and brown hematite.

Subsp. 1. *Brown Iron-froth*.—Colour varying between clove-brown and steel-grey. Occurs massive, superficial, and frothy. Is composed of scaly particles, which are glistening, and have a metallic lustre. Fragments indeterminate, blunt-edged. Intermediate between friable and solid. Soils strongly. Feels greasy to the touch. Is very soft, light, and sometimes even swimming.

It blackens before the blow-pipe without melting, and communicates a yellowish-green colour to borax.

It is generally found coating compact brown iron-stone, and brown hematite.

One of the Shetland islands affords it; and it occurs also in Saxony, the Hartz, Norway, Carinthia, Bareuth, Carniola, and Stiria.

Subsp. 2. *Ochre-brown Iron-stone*.—Colour yellowish-brown, inclining to ochre yellow. Occurs massive and disseminated. Between solid and friable. Fracture earthy. Internally it is dull. Fragments indeterminate, blunt-edged. Soils considerably. Is more or less coherent, and heavy.

Imparts an olive-green colour to borax.

It accompanies the other subspecies; and is found in Norway, Saxony, Bohemia, Bavaria, and Salzburg.

Subsp. 3. *Compact Brown Iron-stone*.—Colour clove-brown of various intensities, passing sometimes to yellowish-brown. Occurs massive, disseminated, and in various imitative forms, as stalactitic, reniform, cellular, dendritic, &c. It sometimes, also, appears in pseudo-crystals, of which the cube, rhomb, and lens have been particularized. Madrepores and corallines, too, have it frequently for their base; as well as other extraneous fossils. Internally it is dull, or very rarely glimmering. Fracture usually even, sometimes earthy and small-grained uneven, and conchoidal. Fragments indeterminate, edges more or less blunt. Streak bright yellowish-brown, bordering on ochre-yellow. Is semi-hard, inclining to hard. Rather brittle. Easily frangible, and heavy. Sp. gr. 3.4771 to 3.551.

It darkens before the blow-pipe, in consequence of the loss of oxygen, and becomes magnetic. Borax receives an olive-green colour from it.

The proportion of its ingredients, as stated by M. D'Aubuisson, in the 75th volume of the "*Annales de Chimie*," is as follows:

	From Bergzabern.	From Videssos.	From Voightberg.
Peroxyd of iron	84	81	69
Peroxyd of manganese	1		3
Silex	2	4	10
Alumine			3
Volatile matter	11	12	13
Loss	2	3	2
			100

The specific gravity of the specimen from Videssos was 3.4.

It is always accompanied with some of the other subspecies; and frequently with quartz, calcareous and heavy spar, and pyrites.

Occurs in Mainland, one of the Shetland isles; the Hartz, Saxony, Silesia, Bohemia, Suabia, the Tyrol, France, Carinthia, &c.

Subsp. 4. *Brown Hematite*.—Its colour, internally, is clove-brown, which passes to yellowish-brown, and brownish-black. It is exhibited under a great variety of other shades, as blueish or iron-black, pinchbeck-brown, bronze-yellow, and sometimes iridescent. Occurs rarely massive; usually in some

of the imitative forms before spoken of. It is sometimes found in pseudo-crystals of a pyramidal shape, with six acute-angled sides. Surface sometimes smooth, and sometimes rough and drusy. Lustre shining or glistering. Internally it is from glimmering to glistering; intermediate between silky and resinous. Fracture fibrous, passing sometimes to small conchoidal. Fragments usually splintery or wedge-shaped; rarely indeterminate. Occurs in distinct concretions. Streak yellowish-brown. Opaque. Semi-hard. Brittle. Very easily frangible, and heavy. Sp. gr. 3.789 to 3.951.

It blackens before the blow-pipe, but does not melt. With borax it enters into ebullition, and produces a dirty yellow-coloured compound.

Its constituent parts, according to M. D'Aubuisson, whose analyses were generally repeated two or three times, are as below stated:

	From Bergzabern.	From Videssos.
Peroxyd of iron	79	82
Peroxyd of manganese	2	2
Silex	3	1
Volatile matter	15	14
Loss	1	1
	100	100

The specific gravity of the former was 3.8, and of the latter 3.9. The specimen from Videssos afforded a slight trace of alumine.

It occurs in the newest primitive, transition, and secondary mountains; but most frequently in the two latter, where it is found lining cavities in veins or beds. Its usual attendants are black and sparry iron-stone, calcareous spar, brown and heavy-spar, and sometimes, though rarely, quartz.

It is found in Voightland, the Fichtelgebirge, Franconia, Hesse, and Nassau.

This species, which is so very abundantly distributed in the German states, is of rare occurrence either in Sweden, Russia, Norway, or England. In the former, it furnishes materials for very extensive iron-works; and the wrought-iron produced from it is very valuable.

Sp. 8. *Sparry iron-stone*. *Spath eisenst. in. Le fer spathique*. *Ferrum ochraceum spatiforme*.

Colour yellowish-grey, which passes into yellowish-brown, clove-brown, and blackish-brown. It tarnishes on exposure either to the air or heat, and then becomes brown or black, and sometimes iridescent. Occurs massive, disseminated, and crystallized. Its crystals are either rhombs, lenses, octahedrons, or garnet-dodecahedrons. They are seldom large or very small; commonly middle-sized and small. Their surface is sometimes smooth, sometimes drusy, and a little rough. Internally it varies from splendid to glimmering; lustre pearly. Fracture foliated. Cleavage triple. Fragments rhomboidal. Occurs in granular distinct concretions. The light-coloured varieties are translucent, especially on the edges; but the dark-coloured opaque. The former give a greyish-white streak; the latter a yellowish brown. It is semi-hard, inclining sometimes to soft. Rather brittle. Easily frangible, and moderately heavy. Sp. gr. 3.300 to 3.810.

It blackens before the blow-pipe, and enters into ebullition with borax, to which it communicates a dirty yellow colour. It always effervesces more or less with acids. According to Bergmann, it is composed of

Oxyd of iron	-	38
Oxyd of manganese	-	24
Lime	-	19
Carbonic acid	-	10
Water	-	9
		<hr/> 100

but it is liable to great variation in the proportion of its ingredients. In a recent examination by Collet-Descotils, the following result was afforded :

Fragments of quartz	-	2.58
Red oxyd of iron	-	48.45
Brown oxyd of manganese	-	1.80
Lime	-	52
Magnesia	-	1.98
Carbonic acid, water, and loss	-	44.67
		<hr/> 100.

Annales de Chimie, t. 58.

The specific gravity of the specimen analysed in this case was 3.693 ; and its colour was brownish-yellow.

It occurs in primitive and secondary mountains ; in the former, in veins ; in the latter, in beds.

It is found sparingly in Britain ; and not very abundantly in Sweden, Norway, Switzerland, Siberia, Bohemia, and Saxony. At Schmalkalden, in Hesse, however, there is a bed from 25 to 30 fathoms thick ; and in different parts of Westphalia, Stiria, Carinthia, &c. it is very plentiful. A whole hill, in the province of Biscay, is composed of it, which is said to have been worked for several thousand years.

It is much used as an ore of iron, and the metal produced from it is considered to be peculiarly favourable for steel-making ; but whether this is any thing more than a mere prejudice, seems greatly to be questioned.

Sp. 9. *Black iron-stone. Schwarz eisenstein. La mine de fer noire. Ferrum ochraceum nigrum.*

This is divided into two sub-species ; compact black iron-stone, and black hematite.

Subsp. 1. *Compact Black Iron-stone* — Colour between bluish-black, and dark steel-grey. Occurs massive, and in various imitative forms. Surface dull, or faintly glimmering. Internally it is bordering on glistening, and its lustre semi-metallic. Fracture commonly conchoidal, sometimes uneven. Fragments indeterminate, sharp-edged. Streak shining, but unchanged. It is semi-hard, brittle, easily frangible, and heavy. Sp. gr. 4.076, according to Wiedemann.

This mineral had for a long time been classed as an ore of manganese, and was removed to the present genus from some particular distinctions that were pointed out by Werner, between the compact grey manganese ore, of which it had usually been considered a variety, and the sub-species now under examination. M. D'Aubuisson, however, in the course of his late researches, has subjected a specimen of it to chemical analysis ; and instead of finding iron to be its principal ingredient, has ascertained it to be almost wholly composed of manganese and silex. This would, perhaps, be a sufficient authority for transferring it to the latter genus again ; but as the Wernerian classification has been uniformly adhered to in the present article, it has been deemed best to continue its enumeration here, and accompany the account of it with the particulars of M. D'Aubuisson's inquiry.

The specimen he examined came from Raschau, in Saxony, and was of a bluish-black colour mixed with grey. It had

a compact fracture, was semi-hard, approaching to hard, and of the specific gravity of 3.6. It consisted of

Peroxyd of manganese	-	-	64
Silex	-	-	13
Volatile matter	-	-	14
Loss (occasioned by an accident in drying some carbonat of manganese on the filter)	-	-	9

100

Annales de Chimie, t. 75.

Considerable difference is very likely to exist in the chemical constitution of this mineral, and the total absence of iron, in the present case, may certainly be regarded as rather an extraordinary circumstance. Indeed, Werner's judgment is much too accurate to admit the supposition, that the varieties which have come under his inspection were destitute of it ; but from the very great produce of manganese in the above analysis, and the general character of the species, in imparting a violet-blue colour to borax, there can be little doubt that this, if not both sub-species of black iron-stone, are, properly, ores of the former metal.

Subsp. 2. *Black Hematite*.—Colour inclining more to steel-grey than the preceding sub-species. Occurs massive and reniform. Internally it is glimmering ; lustre semi-metallic. Fracture delicately fibrous, passing into even. Fragments wedge-shaped. Occurs in granular distinct concretions. In other respects agrees with the preceding.

Before the blow-pipe, both the members of this species melt with borax into a violet-blue coloured glass. No exact analysis has yet been made of the black hematite ; but its chemical constitution is in all probability very much similar to that of the former sub-species.

Black iron-stone is found in primitive and stetz mountains, accompanied with brown and sparry iron-stone and quartz.

It occurs at Naila, in Baruth ; Raschau, in Saxony ; Hesse, the Upper Palatinate, and the Hartz.

Sp. 10. *Clay iron-stone. Thoneisenstein. Le fer argileux. Ferrum ochraceum argillaceum.*

This widely distributed, and highly valuable mineral, is divided into seven sub-species ; reddle, columnar clay iron-stone, lenticular clay iron-stone, jaspery clay iron-stone, common clay iron-stone, iron kidney, or kidney-shaped iron-ore, and pea ore, or pea-shaped iron-ore.

Subsp. 1. *Reddle*.—Colour light brownish-red. Occurs only massive. Principal fracture slaty, glimmering. Cross fracture earthy, dull. Fragments tabular, splintery or indeterminate. Streak lighter than the fracture surface, and more shining. Soils strongly, and may be written with. It is soft, and very soft, sectile, easily frangible ; strongly adherent to the tongue, meagre to the touch, and moderately heavy. Sp. gr. 3.1391 to 3.931.

It decrepitates and blackens at a red heat, and, in a more elevated temperature, melts into a kind of pumice of a greenish-grey colour.

It most generally occurs in the newer clay slate ; and is found in Thuringia, Saxony, Silesia, Salzburg, Hesse, and Siberia.

It is scarcely used for any other purpose than drawing.

Subsp. 2. *Columnar Clay Iron-stone*.—Colour brownish-red, passing sometimes to cherry-red. Occurs massive, and in pieces which are more or less angular. Surface rough and dull. Internally dull, and fracture earthy. It most usually occurs in columnar distinct concretions. Streak blood-red. It is soft, very easily frangible, brittle, meagre to the touch, adheres slightly to the tongue, and is moderately heavy.

It blackens before the blow-pipe, and imparts an olive-green colour to borax.

It is but rarely met with, and appears to be, in some instances, of pseudo-volcanic origin. Its occurrence with porcelain jasper, and other minerals which are evidently of that class, gives considerable colour to the idea; but there are cases, as the one observed by Reufs in Bohemia, where it appeared in the centre of a mountain of clay-slate, that are equally opposite in their evidence.

It is found in the isle of Arran, at Sobruffan, Hofchnitz, Delau, and near Prohn, in Bohemia; at Dutweiler, in Saarbrücken; and Amberg, in the Upper Palatinate.

It yields too small a proportion of metal, even where the mineral is sufficiently abundant, to be at all worked as an ore of iron.

Subsp. 3. Lenticular Clay Iron-stone.—Colour brownish-red, varying to reddish and yellowish-brown, and greyish-black. Occurs massive. Internally it is strongly glimmering, sometimes glistering, and always semi-metallic. Fracture fine earthy, and sometimes flaty. Fragments indeterminate, blunt-edged. Occurs in distinct concretions, which are frequently lenticular, but sometimes granular. The streak varies with the colour of the specimen: generally lighter. It is usually soft, sometimes very soft, and semi-hard. Sectile, inclining to brittle; very easily frangible, and heavy.

Its composition, according to Lampadius, is

Of oxyd of iron	64.
Alumine	23.
Silex	7.5
Water	5.
Loss	.5

100

The black varieties, which occur only in the canton of Berne, are said to yield 90 *per cent.* of iron. The red ore, which is found very abundantly in Bohemia, affords 60 *per cent.*

It is distributed in transition and fletz mountains, and generally unmixed with other minerals.

Besides the situations already noticed, it is met with in Suabia, the Netherlands, Bavaria, Franconia, and France.

It is smelted as an ore of iron, and the brown varieties of it, which contain from 30 to 35 *per cent.* of metal, are much valued on account of the excellent quality of the metal that is produced from them.

Subsp. 4. Jaspersy Clay Iron-stone.—Colour brownish-red. Occurs massive. Internal lustre dull, bordering on glimmering. Fracture flat conchoidal; sometimes even. Fragments rhomboidal, also cubic and trapezoidal. Lighter in the streak. Soft, brittle, easily frangible, and heavy.

It has, hitherto, been only met with in a bed which belongs to the secondary or fletz formation, between Vienna and Hungary.

Subsp. 5. Common Clay Iron-stone.—Colour light yellowish-grey, inclining to ash-grey, and passing into blueish and steel-grey, yellowish, reddish, and clove-brown, brick-red, and brownish-red. These colours, particularly the lighter ones, undergo a change on exposure to the air, generally becoming darker. Occurs massive, and in a variety of extraneous forms, especially of shells and vegetables. Internally it is dull. Fracture earthy, sometimes conchoidal and flaty. Fragments indeterminate, blunt-edged; soft; rather brittle; adheres a little to the tongue; is more or less easily frangible; meagre to the touch, and heavy. Sp. gr. from 2.936 to 3.471.

Exposed alone before the blow-pipe it blackens, but does

not melt. With borax it enters into a sort of ebullition, and produces a glass of a blackish olive-green colour. It varies considerably in the proportion of its ingredients. Some specimens of the mineral yield as much as 40 *per cent.* of oxyd of iron, whilst others do not afford more than 20 *per cent.*, and many even less than that. The following, which will contribute to shew this, are the results of some analyses by Richter and Lampadius.

Oxyd of iron	20.1	33.9	39.	42.5
Oxyd of manganese	1.	1.1		3.
Silex	19.9	23.9	5.	13.8
Alumine	30.2	13.	40.	13.6
Magnesia			6.	
Carbonic acid	28.8	28.1		27.1
Water			9.	
Sulphur			1.	
	100	100	100	100

This subspecies is a very abundant one, and occurs in beds in the secondary or fletz formation.

It is found very plentifully in different parts of England and Scotland; and is also met with in Westphalia, Bohemia, Silesia, the Upper Palatinate, Poland, Russia, Siberia, Italy, and Norway.

Subsp. 6. Reniform iron ore.—Colour yellowish-brown, varying in intensity in the same specimen. The centre is the lightest, and not unfrequently includes a small kernel of an ochre-yellow tint. Occurs in masses from the size of a walnut to that of a man's head, which are most commonly imbedded in clay or shale. Fractured towards the surface, even; in the interior fine earthy. Fragments indeterminate, rather sharp-edged. Internal lustre dull; externally glimmering, semi-metallic. It is composed of concentric, lamellar, distinct concretions, inclosing a nodule, which is often loose. Surface rough; external layers soft; those of the centre very soft; brittle; easily frangible; adheres to the tongue; is meagre to the touch, and moderately heavy. Sp. gr. 2.574.

It does not melt before the blow-pipe, when heated alone; but enters into fusion with borax, and communicates to it a dirty yellow colour.

Occurs in the newest fletz rocks, imbedded in the argillaceous strata that are incumbent on coal.

It is found abundantly in Derbyshire, and some of the neighbouring counties; in Scotland, Norway, Denmark, Bohemia, Silesia, Transylvania, France, and Siberia.

The greatest proportion of the iron manufactured in the midland districts of England, as well as in many parts of Scotland, is obtained from the two foregoing subspecies. The metal which they afford, too, is, generally speaking, of the best quality. This is principally referable to the liberal supply of earthy matter in their composition; for, without a sufficient production of scoria, or cinder, in the blast-furnace, the highly carbonized, and consequently most valuable, varieties of iron cannot be formed. These subjects will be more fully discussed in a succeeding section of the article.

Subsp. 7. Pisiform iron-stone.—Colour yellowish-brown, of different shades, passing sometimes to blackish-brown. This is its internal appearance. Externally, it varies according to the nature of the stratum in which it is imbedded, being reddish, yellowish, and liver-brown, and even yellowish-grey. Occurs in small spherical grains. Centre of the grain dull; lustre increasing towards the surface to glistening. Internal fracture fine earthy; externally, even. Fragments indeterminate, somewhat sharp-

edged. Occurs in concentric, lamellar, distinct concretions. Streak yellowish-brown. It is semi-hard, passing to soft. Not very brittle; easily frangible. Sp. gr. 5.207.

It exhibits, before the blow-pipe, the same appearances as the last subspecies. Subjoined are the results of two analyses of it; the former by Vauquelin, the latter by Mallinchof:

Iron	30	
Oxygen	18	
Alumine	31	
Silex	15	
Water	6	
	<hr/>	
	100	100

This mineral is supposed by Werner to occur in the second stetz lime-stone, and in clay-beds.

It is found in France, Switzerland, Franconia, Hesse, Suabia, the duchy of Wirtemberg, and Dalmatia. In the latter country, it is said to be used by the inhabitants instead of shot.

The greater part of the French iron is extracted from this subspecies. It yields, in the large way, from 30 to 40 per cent. of metal.

Sp. 11. *Bog iron ore. Raseisenstein. Le fer limoneux. Ferrum ochraceum cespitium.*

Werner divides this into three subspecies; morafs ore, swamp ore, and meadow ore.

Subsp. 1. *Morafs ore.*—Colour yellowish-brown. It is sometimes friable, and sometimes approaching to coherent. When the latter, it occurs massive, corroded, and in grains. The former varieties consist of dusty particles. Lustre dull. Fracture earthy. Fragments indeterminate, blunt-edged. Soils considerably. Is meagre to the touch, and light.

Subsp. 2. *Swamp ore.*—Colour dark yellowish-brown, sometimes passing to yellowish-grey. Occurs corroded, vesicular, and amorphous. Lustre dull, sometimes slightly glimmering. Fracture earthy, passing to fine-grained, uneven. Fragments indeterminate, blunt-edged. Streak light yellowish-brown. Very soft; sectile. Easily frangible, and moderately heavy. Sp. gr. 2.944.

Subsp. 3. *Meadow ore.*—Colour, when fresh broken, blackish-brown, passing sometimes to yellowish-brown, and brownish-black. Occurs massive, in grains, tubercle, perforated, and amorphous. Externally it is rough and dull. In the interior it varies from shining to glimmering; lustre resinous. Fracture conchoidal, passing sometimes to small-grained, uneven, and earthy. The conchoidal varieties have the brightest lustre. Fragments indeterminate, blunt-edged. Streak light yellowish-brown. Soft; brittle. Very easily frangible, and heavy.

Bog-iron ore in general blackens before the blow-pipe, without melting. It enters into ebullition with borax, and produces a glass of a dirtyish yellow colour. The only member of the species that appears to have been subjected to analysis is the meadow ore: and it is constituted, according to the information of M. D'Aubuisson, of

Peroxyd of iron	61
Peroxyd of manganese	7
Silex	6
Alumine	2
Volatile matter	19
Phosphoric acid	2.5
Lime, sulphur, and loss	2.5

100 Annales de Chimie, t. 75.

The volatile matter, which so constantly forms a part of the results quoted from this chemist, almost exclusively consists of water; and it was with a view, indeed, of ascertaining the proportion of this ingredient, that his analytical labours were principally commenced. He supposes it to be an essential constituent of the different minerals he has examined, and proposes to arrange them under the class of *hydrats*.

The present species is smelted in some of the countries that afford it, and yields, in the large way, from 30 to 35 per cent. of metal.

It occurs in the newest formations, and is conceived to be continually deposited in marshy places, from the evaporation of the water that has held it in solution. The preceding subspecies are products of this process at different stages; and the order in which they are arranged is indicative of the date of their formation.

It is found in different parts of the Highlands of Scotland, the Hebrides, Orkneys, and the Shetland islands. Poland and Prussia contain considerable quantities of it; as also do Brandenburg, Courland, Livonia, and Lithuania. Its occurrence is more frequent in the northern than in the southern countries of Europe.

Sp. 12. *Blue iron earth. Blaue eisererde. Le fer terreux bleu. Ferrum ochraceum ceruleum.*

Before it has been exposed to the air, its colour is greyish-white, but afterwards becomes indigo-blue of different shades, and sometimes smalt-blue. Occurs massive, and disseminated; and is composed of dull, dusty particles, which are friable and cohering. Soils slightly. Feels meagre, and is moderately heavy.

Before the blow-pipe, it becomes of a reddish-brown, and afterwards melts into a brilliant black globule, which tinges borax of a deep yellow. It is readily soluble in acids. Bergmann had supposed it to be a native *Prussian-blue*; and it has received a place in many mineralogical systems, under that name, from the same belief: but an analytical examination of it by Klaproth seems to prove it to be a compound of phosphat of iron and alumine.

It occurs in nests in clay-beds, amongst bog-iron ore, and incrusting turf and peat.

It is found, under the latter circumstances, in the Shetland islands; it also appears in Iceland, Saxony, Silesia, Swabia, Bavaria, Poland, Siberia, Russia, and Sweden.

Sp. 13. *Pitchy iron ore. Eisenpecherz. Fer phosphat.*

Colour pitch-black, passing sometimes into blackish-brown, and even deep reddish-brown. Occurs massive. Surface earthy, and dull. Internally it is glistering; lustre resinous. Fracture foliated, conchoidal, and sometimes fine-grained, uneven. Fragments indeterminate, tolerably sharp-edged. Opaque; semi-hard; brittle. Not very easily frangible, and moderately heavy. Sp. gr. 3.956.

It melts easily before the blow-pipe, and forms a black enamel. According to Vauquelin, it consists of

Phosphoric acid	27
Oxyd of iron	31
Oxyd of manganese	42
	<hr/>
	100

Is found near Limoges, in France.

Sp. 14. *Green iron earth. Grüne eisererde. Le fer terreux vert. Ferrum ochraceum viride.*

This is divided into two subspecies; friable green iron earth, and coherent green iron earth.

Subsp. 1. *Friable green iron earth.*—Colour fikin-green. Occurs massive, and disseminated; and consists of particles

which are without lustre. Fragments indeterminate; soils; is soft, and very soft. Sometimes friable. Meagre to the touch. Easily frangible, and moderately heavy.

Subsp. 2. *Coherent green iron earth*.—Colour rather darker than the last subspecies. Occurs massive, and corroded. Internally dull. Fracture fine earthy, passing into even, and sometimes into splintery. Fragments indeterminate; soft. Rather brittle, and inclining to heavy.

Before the blow-pipe, it becomes first red, and then of a dark brown; but does not melt. It tinges borax of a yellow colour, inclining to olive-green. No exact analysis has been made of this species; but it is supposed by Werner to have iron and phosphoric acid for its principal ingredients.

It is a rare mineral, and has hitherto been only found at Braunsdorf and Schneiberg, in Saxony, where it occurs in veins: in the former place, accompanied with quartz and pyrites; and in the latter, with quartz and native bismuth.

Sp. 15. *Cube-ore. Wurfelerz. Fer arseniate.*

Colour olive-green, of different degrees of intensity. Occurs massive, disseminated, and crystallized in small and very small cubes, which are sometimes flattened and truncated at the angles. Planes of the crystals smooth and splendent. Internally it is glitening, and its lustre between pearly and adamantine. Fracture imperfect foliated. Fragments indeterminate. Occurs in granular distinct concretions. It is translucent; soft; brittle, and gives a streak of a straw-yellow colour. Sp. gr. 3.000. It appears sometimes in the form of a reddish-yellow powder, which is thinly distributed over the surface.

Before the blow-pipe it swells up, and emits an arsenical odour; melting afterwards into a grey metallic globule, slightly tinged with yellow. From the analysis of Chenevix, it appears to be composed of

Arsenic acid	-	-	31.
Oxyd of iron	-	-	45.5
Oxyd of copper	-	-	9.
Silex	-	-	4.
Water of crystallization			10.5

100

It occurs in veins, accompanied with some ores of copper, quartz, mica, and feldspar.

The only places that have, hitherto, afforded it, are the mines of Carrarach and Muttrell, in Cornwall.

Until the account published of this mineral by the count de Bournon, and Mr. Chenevix, in the Philosophical Transactions for 1801, it was mistaken for an arseniate of copper.

§ 2. Assay and Analysis.

Since the metal contained in every ore is of so much greater specific gravity than any other of its accompanying ingredients, it will be easy to form a tolerable idea of the value of an iron-ore by the weight of a given bulk.

Previously to working any iron-ore it should be very minutely analysed, both in the humid and dry way. By the humid process we shall ascertain the exact proportions of its constituents, without which it would be a mere work of chance to attempt to extract the iron in the metallic form.

When we are acquainted with the nature of the earthy matter in combination with the ore, we know with the greatest certainty what substances we ought to add in the crucible, for the purpose of eliminating the metal. All such substances are called fluxes, merely because they form fusible

compounds with the earthy matter of the mineral. It is to this treatment of a small quantity of the ore that we give the name of assaying.

The process by which the component parts are ascertained, consists in subjecting a small quantity of the ore in fine powder to the action of an acid, and sometimes to an alkali. By this means the whole is dissolved, and the different materials of which it is composed are separately precipitated by different chemical re-agents. The process, however, varies considerably with the nature of the ore to be examined.

Iron ores, as subjects of analysis, are divided into three heads; namely, sulphurets, oxyds, and salts.

The first are distinguished by their general bronze colour, but more particularly by the suffocating smell of sulphureous acid gas, which they afford by being heated to redness in the open air. The second consist of iron united with oxygen, and are by far the most common of all. Nearly the whole of the iron-ores in use are of this kind, containing also different proportions of earthy matter in their composition.

The third division comprehends such as consist of the oxyd of iron combined with some acid, and hence are called salts. The principal varieties of these are the phosphates, sulphates, arseniates, and carbonates.

The apparatus employed in the humid analysis will be a lamp fitted up with different-sized sliding-bearers, a silver crucible, and small portable furnace, with a sand-bath, and one of water, for drying precipitates; capsules of glass and porcelain; precipitating glasses, funnels, and filtering paper. For reducing the ore to powder, a mortar of hardened steel will be first necessary, and afterwards one of agate, to grind it very fine. Accurate weights and scales will be highly requisite, with cups of silver or platina.

The re-agents wanted will be sulphuric, muriatic, and nitric acids. Pure potash, soda, and borax, in the solid form. Solutions of the same, and also the pure aqua ammonia. The fully saturated carbonates of all the alkalis, and the subcarbonates of the same. The triple prussiate of potash and iron; and, when merely used as a test, prussiate of lime will answer. The analyst should, also, have in his possession powders or solutions of all the separate substances of which the mineral is supposed to consist, for the purpose of comparing real results with those obtained in his experiments.

If the ore to be analysed be a pure sulphuret, 100 grains, or any other given weight, may be reduced to powder, observing to weigh it after the operation, to see if any of the mortar has been abraded, which, when the ore is very hard, is to be expected; and the increased weight must in that case be noted down.

Let this powder be boiled with nitric acid in a long narrow-beaked glass vessel, which should be very thin at the bottom, to avoid cracking. By this method the sulphur of the ore will be converted into sulphuric acid; part of the nitric acid will be decomposed, and most of the remainder fly off, so that the resulting fluid will principally consist of the iron dissolved in sulphuric acid.

To this solution add the muriat of barytes, till a precipitation ceases to take place. When the precipitate has subsided, and the fluid is become perfectly clear, gently pour off the liquor, which is a solution now of iron in the muriatic acid. Let the precipitate, consisting of sulphat of barytes, be repeatedly washed with hot distilled water, till the liquid gives no precipitate with nitrat of silver, and afterwards add the washings to the fluid first poured off. After this white powder has been dried on the steam-bath, which is an apparatus constructed for this particular use, let it be weighed, and for every 100 grains of the substance allow 21.3 of sulphur. To the liquid parts which contain the oxyd of iron,

add a clear solution of the sub-carbonat of potash. Let it boil for a little time, and the oxyd of iron will subside. Wash it and dry it as above, afterwards weighing the product. The quantity of oxygen in the oxyd of iron thus obtained, may be known by the quantity of iron obtained from it in the process of assaying, which we shall afterwards give. If the ore consist of oxygen and iron only, it may, without any previous treatment, be referred to the dry process. When, however, earthy matter is combined with it, the humid analysis should be resorted to, which requires a different mode of proceeding to that already given.

Let 100 grains of the ore be reduced to a fine powder, as above directed, observing to weigh it afterwards, for the purpose of ascertaining whether any of the materials of the mortar be mixed with it. The matter so added, if it be acquired from the agate mortar, may be deemed pure filix.

To this powder add 300 grains of dry potash, in a silver crucible, capable of holding about six or seven ounces. Pour to the mixture a very little water, just sufficient to moisten the whole. Apply a gentle heat in the first instance, to prevent the mass from swelling too much, and gradually increase the temperature till the crucible is red-hot. The mass will now be in a state of fusion more or less perfect, according to the quantity of filix contained in the ore. If, from a great proportion of alumine being present, the fusion should be very imperfect, more potash must be added, and the heat continued and raised as high as the crucible will bear. When the crucible, with its contents, are sufficiently cooled, let both together be put into a capsule of porcelain, and nearly filled with distilled water. The whole should then be set upon a sand-bath, and boiled for some time, taking care to stir it very frequently. This will detach the matter adhering to the crucible, and if any filix remain unacted upon, it will be dissolved by the potash.

Let the whole be now saturated with muriatic acid, and even added a little in excess; and then gently boiled till all the liquid is evaporated. During this, the mixture must be constantly stirred; and particularly at the time the mass is becoming dry.

To this residuum let a large quantity of distilled water be poured. All the substances soluble in the acid will be now taken up. If it contain filix that will be left at the bottom. Let the whole be decanted into a narrow tall glass vessel, to suffer the filix to subside. Carefully pour off the clear liquor, and then add fresh hot distilled water, and continue to do so till the fluid does not cause a precipitate with nitrat of silver; observing to save all the washings which are acted upon by that test. The remaining water may now be evaporated from the filix, and the powder, being heated red-hot in a crucible of silver or platina, should be then weighed. If it be pure, it will be of a delicate white colour, not adhering to the fingers, as is the case with some of the other earths.

The solution containing the remaining substances should be evaporated to as small a quantity as possible, so that the fluid remain liquid and clear. To this let a saturated solution of the subcarbonat of potash be added, and afterwards boiled a few minutes. By this means, the whole of the ingredients will be precipitated together, and when all of them have perfectly subsided, decant off the liquor, repeatedly washing it with hot water. The first decanted liquor, with the washings, may be thrown away. Lastly, evaporate the remaining water, till the solid matter is of a pulpy consistence. To this, in a capsule of good porcelain, add a solution of pure potash. The alumine will be thus dissolved, while all the other substances will remain un-

touched. Let this fluid be poured off, and fresh water mingled with it, to take away all the alumine. Then, to the mixture containing the alumine, add not only as much acid as will saturate the potash, but also a quantity sufficient to dissolve the alumine, when the liquid will be quite clear. Finally, to this pour in carbonat of ammonia, till no more precipitate falls down. The precipitate, when washed and dried as above directed, and heated to redness in a silver crucible, may be considered as pure alumine.

The residuum from which the alumine was last taken is now to be dissolved in sulphuric acid, diluted with a large quantity of water, the acid being slightly in excess. This solution may contain magnesia, iron, and probably manganese. If lime were present, it will be left insoluble at the bottom of the vessel, in the state of sulphat of lime. The small portion of this substance dissolved by the fluid, may be precipitated by the addition of alcohol. The powder, when collected and dried at a dull red heat, must be weighed; allowing for every 100 parts 42 of pure lime. The solution from which the lime was separated, must next be saturated with a solution of the neutral carbonat of potash. In a few minutes the iron will be precipitated in the state of oxyd, while the magnesia and manganese will be dissolved by the carbonic acid. The iron must be separated, dried, and weighed. If with the solution containing the magnesia and manganese a solution of hydrosulphuret of potash be mingled, the latter will be precipitated in the form of a sulphuret; and this being washed and heated till the sulphur is driven off, the oxyd of manganese will be left in sufficient purity.

The magnesia still held in solution may be precipitated by adding a sufficient quantity of pure potash. The product must be heated to redness, and weighed. The weights of the different substances being added together, will, if great care has been used, be within one or two *per cent.* of the quantity originally submitted to experiment. If the deficiency be considerable, some mistake must have been made, and it will be necessary to repeat the analysis.

In the examination of salts of iron, nothing more is requisite than to disengage the acid with which the iron is combined. The arseniat of iron, for example, must be boiled with potash, which will separate the arsenic acid, and leave the oxyd of iron but very little acted upon. The arsenic acid may be afterwards precipitated by nitrat of lead; allowing for every 100 parts of the arseniat of lead, when dried, 33 parts of arsenic acid.

If the ore be a pure carbonat, to 100 grains in powder, add an equal quantity of sulphuric acid, in a glass vessel which can be placed over a lamp. Heat the mixture for some time, stirring it with a glass rod. The carbonic acid will be thus expelled, and its quantity will be indicated by the loss of weight sustained. Care should, of course, be taken that the heat be not too great, otherwise the evaporation of fluid matter may create error in the experiment. The iron may be afterwards treated as in the analysis of the earthy ores, and its quantity ascertained, by the methods there described. Having learned the exact proportions of the ingredients united in the ore, we may, with some degree of certainty, proceed to the assay by the crucible and fluxes. If the ore consist of oxyd of iron simply, nothing more is necessary than to introduce it into a crucible with about half its weight of charcoal powder, and any substance susceptible of vitrification, so as to keep off the air. This may be either pounded glass, or equal parts of lime and clay. But perhaps the best substance that can be employed, is the most fusible part of the blast furnace cinder, which is the least coloured with oxyd of iron. This may be employed in quantity

amounting to about half the weight of the mineral to be assayed.

The earthy iron ore must be treated according to the result of the humid analysis; such earth being added as a flux, as will make the most fusible compound with that found by analysis to be present. The carbonaceous matter may be from $\frac{1}{3}$ to $\frac{1}{2}$ the weight of oxyd of iron.

The furnace best calculated for these experiments is called an assay furnace, and is capable of producing a great heat. See FURNACE.

The crucibles should be very small, not capable of holding more than three fluid ounces; and they should be provided with covers turned to them in a lathe before they are burned. The assay may be deemed finished when the whole is in a state of fusion, and the metallic button separated, which, being weighed, will give the *per centage* of iron in the ore.

§ 3. *Reduction of Ores, and Manufacture of Pig-iron.*

Although iron in its pure state is almost an infusible substance, it is capable of assuming the liquid form, by being combined with other matter. With sulphur it forms a fusible mass, of which we shall treat hereafter. It is also rendered fusible at a temperature something higher than that required to melt copper, by being combined with about $\frac{1}{12}$ th of its weight of carbon. It is to this compound in different proportions that the name of pig-iron is given, and it is so denominated, because it is cast into masses of a semi-cylindrical shape, called *pigs*.

The fusibility of this compound of iron and carbon, enables us to extract the metal from the ore to the greatest advantage. It is now common, particularly in our own country, to obtain the iron in this form, previous to making it into bar, or malleable iron. Formerly cast metal was not much in use, except for the manufacture of bar-iron and steel; while in the present day, a much greater proportion of it is consumed in that state than in any other; and the majority of our furnaces, too, are solely employed for this branch of manufacture.

The process by which pig-iron is obtained from the different iron ores is called *smelting*; and the furnaces employed for the purpose are called *smelting*, or *blast furnaces*. See BLAST furnace, and BLOWING.

The ores of iron require different treatment in the smelting process, according to the quantity of heterogeneous matter with which the metal is combined.

In all the ores the iron is in the state of oxyd, and would at least require a strong heat in contact with combustible matter for their reduction. In most, the oxyd of iron is combined with a considerable proportion of earthy matter, and they are then denominated *iron-stones*. These may be generally divided into two classes; the one called argillaceous, from abounding with excess of alumine, or clay; and the other calcareous, from lime being their principal earthy constituent. The former of these iron-stones is by far the most abundant in this country.

But, besides the earthy matter and oxygen in this class of metallic minerals, many of them contain sulphur, which is doubtless combined with the iron in the state of pyrites. Arsenic and manganese are also sometimes united with them. Of the above, the arsenic and sulphur are extricated, previously to smelting, by the process called *roasting*. For this purpose, the stone is stratified with refuse pit coal, and burnt in large heaps in the open air. The heat is sufficient to dissipate the greatest part of the above volatile materials, leaving behind the earth and oxyd of iron; and also the manganese, when the ore abounds with that metal.

In the process of smelting, two things are absolutely essential to the separation of the iron. First, the metal itself must be rendered fluid, which will then, by its great specific gravity, descend to the lowest parts of the furnace, and some other compound must, at the same time, be eliminated in a liquid form, so as to float upon its surface, and defend it from the influence of the blast. If the ore consisted of iron and oxygen alone, the carbon of the coke would combine with the oxygen; and an excess of carbon would also unite with the iron to render it liquid at that temperature; but here would be a deficiency of the fluid vitreous matter necessary to the defence of the iron from the oxygen of the blast. Hence it will be necessary to employ some substance with such iron-ore, which shall be capable of forming a liquid scoria, or cinder, for the preservation of the carburated iron, when once obtained. So far as observation has dictated, it would seem that the cinder cannot be too perfectly fluid. The principles on which the fusibility of the cinder depends, are not simply confined to the materials used in the smelting of iron, but refer to all compound fusible matter with which we are acquainted. It may be observed, in general, and, indeed, almost without exception, that the fusibility of an alloy of two metals is fusible at a temperature much less than the arithmetical mean between the fusing points of the metals themselves. For instance, an alloy of lead and tin is more fusible than either of the metals composing it, and a similar mixture of copper and silver may be used as a solder for either silver or copper separately. This property is not less conspicuous in the earths. None of them in their *pure* state can be fused in our hottest furnaces; nor scarcely with a stream of oxygen gas; although certain proportions of them are, together, fusible at the heat of a moderate air-furnace. Lime and clay, when separately taken, may be considered as incapable of fusion at any degree of heat, yet produced in furnaces; and still, in certain proportions, they are too fusible to be made into even bricks or crucibles. It will appear, from these facts, that the iron-master cannot pay too much attention to the subject of the relative fusibility of the earths in different proportions. Most of the iron-ores of this country are argillaceous; that is, consist, besides oxyd of iron, of a small quantity of siliceous or flint, and a large proportion of clay. Limestone has always been employed for such ores, and, by combining with the clay and flint, as well as with a small portion of the oxyd of iron, forms a scoria or cinder, easily capable of fusion. Since, however, the proportions of these earths in the ore cannot be uniform, the quantity of limestone to be added ought to vary according to circumstances. We may hence infer, that if the fusibility of the cinder depends upon the particular proportions of the earths present, the iron-master ought to possess a very perfect knowledge of the relative fusibility of different combinations of these bodies, and being at the same time aware of the component parts of the ore to be reduced, he will not be at a loss what should be added in the furnace, for the purpose of producing the most fusible cinder. But it will be proper here to observe, that the earths present, however accurate may be their proportions, will not of themselves form a cinder of sufficient fusibility, without the united aid of the oxyd of iron. This fact will be very familiar to those who have had experience in the use of fire-bricks. Clays which are free from that ingredient do not burn of a red colour; and hence the white appearance of fire-bricks is a tolerable test of their goodness. But those, on the contrary, which exhibit a redness on being fired, are easily fused, and unfit, consequently, to be used in those situations which are exposed to great heat. The proportions of lime, clay, and oxyd of iron, necessary to constitute the most fusible com-

pound, has not, as we have yet heard, been directly ascertained by experiment. An inquiry, undertaken with this view, would, however, be of great importance to the iron-master. It might be effected in two ways; first, by mixing different proportions of the materials employed; and, secondly, by a direct analysis of the most fusible part of the blast-furnace cinder, and that with which the best and most carbonated iron has been produced. The cinder which fuses at the lowest temperature will be best known by its fracture after cooling. It may, in general, be deemed good in proportion to its earthiness when solid, and particularly should the outer crust appear glassy and transparent. A reason may be given for this appearance, by reference to some facts announced by sir James Hall and Dr. Hope, in accounting for the opacity of the whin-stone. They found that when common flint-glass, which is more fusible than the blast-furnace cinder, was allowed to cool slowly, the mass became opaque, and put on a stony appearance. They hence concluded, that the whin-stone might have been transparent, and have possessed a glassy fracture, had it been cooled rapidly. The inference to be drawn from this will be obvious; for the more fusible the cinder, the longer it is in cooling, and consequently the more opaque. What strengthens this idea, too, is, that the exterior of a mass of cinder is more transparent, almost constantly, than the interior; and the centre of that in particular, under which the best iron is made, having a stony fracture, with a thin vitreous shell surrounding its outside. In beginning to work any new ore of iron, the first step is to analyse it, both in the dry and humid way. By the first, we get the *per centage* of iron in the ore; and by the second, we become acquainted with the quality and proportions of its earthy matter. The next step is to analyse the coal to be employed, for the purpose of ascertaining the quantity of carbon it contains, and also the nature and proportions of its earthy residua. These facts being clearly made out, there will be nothing necessary but to add to these materials a proper mixture of such substance as will make the most fusible cinder. If the ore be argillaceous, or, in other words, if clay predominate, lime is to be the material employed. Indeed, ores of this description are so very common, that lime has been thought the only substance to be used, under all circumstances, for the purposes of a flux; and so completely ignorant have the iron-makers been of the philosophy of the process, that it has even been attempted to be added when the ore has already abounded with calcareous ingredients.

Keeping in view the principles we have just laid down, the management of the calcareous ore will be equally easy with the mode of working the argillaceous; since, in such case, we have only to employ clay for the flux instead of lime. But the best method would, perhaps, be, if the component parts of an argillaceous and a calcareous ore were sufficiently well known, to mix the two together in proper proportions.

Whatever may be the substance employed, whether it be limestone for an argillaceous ore, or clay for a calcareous ore, it should be very minutely analysed, as those substances are scarcely ever found in a state of purity. The lime should, if possible, be the shell limestone. At all events, the magnesian stratum should be avoided, since that substance tends much to lessen the fusibility of earthy compounds. Some substances, to which we give the name of clay, frequently consist of a large proportion of some other earth.

Another thing to be attended to, also, is the state of oxydation in which we find the iron-ore.

If it be highly oxydated, more of the carbonaceous matter will be required for its reduction, and in all probability a

longer time; but, besides this, a greater quantity of the oxyd of iron will combine with the earthy matter, which, although it may contribute to the fusibility of the cinder, a large portion of the iron will be lost. On the contrary, when the iron is in a low state of oxydation, the whole of the iron may be apt to combine with the carbon, and the earthy matter may not get a sufficient quantity of the oxyd to render it, in a proper degree, fusible. In such case, it would be necessary to add some oxyd of iron, which might more easily vitrify and enter into the composition of the cinder.

The coal employed in the smelting of iron, for the purpose of being coked, is commonly laid in heaps in the open air, and afterwards set on fire. When the combustion has gone on to a certain degree, the fire is checked by covering it with dust and preventing all possible access of air. For farther particulars, see COKE.

It is essential that the coke should be harder than it can generally be made in the open air without considerable waste; and we recommend, therefore, the method employed in making the cokes for melting steel. The coal, which is very soft, is piled up in ovens of the shape of an erect frustum of a cone. The air is let in at an aperture near to the bottom, which is contracted in size as the combustion becomes rapid, and ultimately closed. The whole mass will at this time have acquired such a degree of heat, as not only to drive off all the volatile matter, but to render the coke extremely hard. There is a considerable saving in this mode of coking, and the coke is not only more compact, but better adapted for the generality of ores of iron.

In smelting the argillaceous ore, the proportions of the roasted ore, and the limestone, are governed entirely by the coke employed. The latter is always a fixed quantity, and the ore and limestone are varied according to the quality of the iron to be made and the working order of the furnace. In proportion as more or less of lime and ore are added to the standard quantity of coke, the furnace is said to carry a greater or less burthen.

It would be useless to give any precise proportions of the ore and limestone to a given quantity of the fuel, since they are found to vary with the nature of the coal in use; and, what is not a little remarkable, the proportions will frequently vary in two furnaces working with the same coal, and even in the same furnace at different times.

The burthen of the furnace will also vary with the quality of iron to be made, that is, as it is required to contain more or less carbon. In making the dark-grey iron called N 1, and which contains the greatest proportion of carbon, the burthen must be less than that required to make the less carburetted iron, commonly called white iron, or *forge-pig*.

To give a general idea of the proportions of the materials, we shall present in detail, the quantities used at a blast-furnace, making in general good melting iron, which is of an intermediate quality between N 1 and the *forge-pig*. The ore is argillaceous, containing about 27 *per cent.* of iron; the coal rather soft, but having a good proportion of carbonaceous matter; and the limestone good, being of the shelly kind before spoken of. The furnace is about 45 feet high, and 12½ feet diameter in the widest part. It works with a bright *tuyere*, and receives from the blast about 2500 cubic feet of air in a minute, through a circular aperture of 2½ inches in diameter.

The average charges of coke *per shift*, as it is termed, or in the space of 12 hours, are 50 (each 2½ *cent.*), or nearly seven tons. The calcined ore for good melting iron is about the same quantity; and for *forge-pig*, or the least carburetted

variety, fix of coke to seven of ore. The limestone unburnt, under the same circumstances, is to coke as four to eleven; and, for melting metal, retains a similar ratio. With the above charge per day, that is, for 12 hours, this furnace makes on the average about 40 tons of melting iron per week.

Some furnaces carry so little burthen as not to yield more than 13 or 14 tons weekly; whilst others, particularly in South Wales, produce, with the same sized furnace, as much as 60 and even 70 tons in an equal time. The burthen of these furnaces is very great, the ore to the coke being in some cases as 13 to 7; and the quality of the iron is uniformly inferior. Since the cavity in the furnace is constantly kept full of the above materials, it may easily be conceived that the whole must be in many intermediate stages, from the fully melted iron to the unchanged ore. At the point where the greatest heat is produced, which will be a little above the level of the blast, every thing capable of fusion will be assuming the liquid form. We cannot, however, for a moment suppose, that the iron at this point is in a state of oxyd, since it would of necessity be all vitrified, and enter into the composition of the cinder. If the iron, even in its carburetted form, were to remain long at so great a temperature, and within the influence of so much oxygen, it would first lose all its carbon, and ultimately pass into the state of vitreous oxyd. As, however, the oxygen of the blast rises in the furnace, it comes in contact with the carbon of the coke, and is very soon converted into carbonic acid gas. That point in the furnace, therefore, where the whole of the oxygen has entered into combination with carbon, may be denominated the commencement of cementation, or the point where the oxyd of iron is first deprived of oxygen, and ultimately saturated or cemented, as it is termed, with carbon. From this point to the top of the furnace the process of cementation is going on with different degrees of rapidity, proportionate to the temperature. It is found by experiment, that if a piece of iron-ore, particularly any of the oxyds that contain but little earthy matter, be exposed in a close vessel in contact with carbon, it will first lose the whole of its oxygen, and afterwards become so saturated with carbon, as to be capable of fusing into the best pig-iron. Hence it appears that the reduction of the ore, so far as relates to the deoxydation and carbonization of the iron, may take place at a temperature below fusion, and without the mass of ore changing its form. The ore exposed to the carbonaceous matter in the cementing part of the furnace, must as completely undergo a similar change as if it were in the closest vessel; for the oxygen is excluded by the presence of carbonic acid gas. When the carbonized, but yet solid, iron, in the form of the ore, falls below the cementing point, or perhaps short of that, it begins to fuse. The earthy matter of the ore, being in contact with lime, begins also to assume the liquid form; and whilst the melted metal is exposed to the oxygen of the blast, a small portion of oxyd of iron is produced, which will enter into the composition of the cinder, and thus tend to increase its fusibility. The liquid iron now drops into the chamber of the furnace called the *hearth*; and the liquid cinder, being of less specific gravity, floats upon its surface, completely defending it from the oxygen of the blast. Hence we see that the column of the blast-furnace may be divided into three portions; the upper portion, or cementing part; the middle, or melting part; and the chamber, or hearth, where the metal is preserved till it is in sufficient quantity to be run out into pigs. The cementing portion is by far

the most extensive, and will vary in its extent with the strength of the blast.

Since the combustion must be in proportion to the quantity of oxygen consumed in a given time, the heat of the furnace will depend upon the quantity and velocity of the air blown into it to a certain extent. If the blast should have too great a velocity, the oxygen would pass through a greater space in the furnace than is desirable before it was disposed of, and the cementing portion would be lessened in consequence. On the contrary, if the velocity were too little, the heat would be confined to the vicinity of the tuyere, and the cementing, as well as the melting processes, would be retarded for want of heat.

When the blast is sufficient to generate the necessary heat for melting the cinder and the metal perfectly, the extent of the cementing portion will depend upon the height of the furnace. This gives us one very satisfactory reason, why a furnace is required to be higher for the use of coke, than when it is heated with charcoal; since the carbon of the latter enters into the composition of the iron with much more facility than that of the former.

According to experiment, it appears that the facility with which carbon enters into combination with iron, in a close vessel, is inversely as its aggregation or cohesion. Hence it is found, that the carbon obtained from animal substances, which is soft and porous, is best calculated to convert iron into a carburet.

It will appear from the last observation, and from what has been said on the nature of coke, that the carbon employed for cementation should be mechanically different from that required to generate the great and permanent heat necessary to the fusion of the materials. The one in the cementing portion should, therefore, if it were practicable, be surrounded with coke of the softest kind, while the materials within the influence of the blast, and occupying the melting portion, should be supplied with such as is harder.

In making the most highly carbonized iron, or what is called N° 1, it sometimes happens that a portion of the iron unites with a great excess of carbon, forming a substance, which, when cold, appears in bright shining scales. It is found to possess most of the properties of plumbago, differing from that substance only in containing less carbon. This carburet is no doubt in the liquid form in the furnace, and, being of much less specific gravity than the iron, floats upon its surface. It is so much more infusible than the metal, that before the iron enters the moulds of the pig-bed it is seen swimming at the top in the scaly form before mentioned.

This substance is called by the workmen *kjfb*; and whenever it appears, is a certain sign that the furnace is working on the best sort of iron. So surely, indeed, is it the case, that N° 1, or the most highly carburetted metal, has received the epithet of *kjfb*, because *kjfb* is the common attendant on its production.

The most remarkable and anomalous circumstance presented in the smelting of iron, is the difference in quantity and quality of the iron made in winter and in summer, when all other things are equal. It is a fact well ascertained, that in order to make the same quantity and quality of iron in summer as in winter, the furnace will not carry so great a burthen, and, at the same time, the means of generating heat requires to be increased.

Various opinions have been given to explain this curious fact. Some have supposed that the proportion of the oxygen was less in the atmosphere in summer than in winter. Others,

that the excess of moisture contained in the air in summer above that in the winter, might explain the phenomenon. Whatever may be the cause of this difference in the blast-furnace, the same may equally be referred to common fires, which, it is well known to every one, are much hotter in winter than in summer. If the Lavoisierian doctrine of combustion were true, we should not expect that the power of air to generate heat would vary with the temperature, since the same caloric which had contributed to dilate the oxygen in summer, would be given up when the oxygen combined with the carbon. Unfortunately for that doctrine, however, we find that the quantity of heat generated during the combination of oxygen, is directly as the quantity of oxygen, whatever may be its state, whether solid, liquid, or aeriform.

It appears from general observation, that the difference in the quantity and quality of the iron made in winter and summer may be, in a great measure, referred to changes arising from variation of temperature. The average result of this atmospheric influence is different with different blast-furnaces, and, indeed, with the materials employed; but in general the quantity varies in winter and summer from $\frac{1}{4}$ th to $\frac{1}{2}$ th, besides the alteration of quality, which in some furnaces cannot be prevented by any change in the burthen.

If the whole of this difference depend upon the temperature of the blast sent into the furnace, we must expect to find it either in the increased rarity of the air, or in the presence of moisture, which exists more abundantly in the atmosphere in summer than in winter; or, perhaps, it may be attributable to both these circumstances.

Soon after the constituent parts of water were discovered, some iron-masters attempted to produce combustion by blowing steam into the furnace. But, notwithstanding the great proportion of oxygen existing in aqueous vapour, their expectations were far from being realized, and the scheme was given up by them under a firm conviction that it never could succeed.

This experiment, however, served to shew that no more mischief might be expected from the vapour of water in the atmosphere, than its merely excluding a portion of oxygen. Conceiving it, therefore, to have no other influence in the furnace, we will submit some calculations to the reader, in order to shew the absolute difference in the quantity of oxygen sent into the furnace in winter and in summer, and to ascertain what share of the defect may be attributed to this circumstance, or whether the whole may not safely be referred to it.

We have much to regret that we are not in possession of more experiments as to the temperature of the air sent into the furnace at different times of the year. The mere temperature of the atmosphere is not sufficient for this purpose, since the air gives out much heat by compression in the blowing cylinder. In a former part of this work (see *BLAST-furnace*), a table of some observations was given, on which, as far as they go, reliance may confidently be placed. In this table the temperature of the air was stated when it entered the blowing cylinder, and after it had been compressed into a vault, from which it passed into the furnace. If we take the temperature on its entrance into the furnace in winter at 50° , and in summer at 100° , the difference will be 50° , and the variation in the quantity of oxygen will be inversely as the increased volume of the air. It is found that elastic fluids are augmented in bulk by one degree of Fahrenheit $.00208$ of the whole. Therefore, the quantity of oxygen at 50° will be to that at 100° as $1 + (100 -$

$50) \times .00208 : 1$; and the oxygen, consequently, in summer will be $.104$, or little more than $\frac{1}{10}$ th less than in winter.

The defect arising from the relative quantities of moisture contained in the air in winter and summer will be very trifling, except where the water-regulator is employed instead of the air vault or common regulator. (See *BLAST-furnace*.) When the air does not come in contact with any thing moist after entering the blowing cylinder, in order to learn the quantity of water present, we have only to ascertain the relative proportions of vapour existing at the respective temperatures of the atmosphere in winter and summer. It appears from a theorem, which we have founded upon Mr. Dalton's ingenious experiments upon evaporation and the force of vapours, that the quantity of water in air at 32° , at which temperature we suppose it to enter the furnace in winter, is equal to 2.04 grains in each cubic foot. This, in weight, is $\frac{2.04}{561}$; and in bulk, vapour being

to air at 32° as 274 to 561 , equal to $\frac{2.04}{274}$ of the whole, or $.0075$. The summer air, which we take at 55° , contains 5.32 grains in a cubic foot; a quantity amounting in weight to $\frac{5.32}{524}$, and in bulk to $\frac{5.32}{274}$, or $.019$ of the

whole. The difference $.0115$ is the deficiency of common air in summer, arising from the presence of aqueous vapour; and makes the total variation in the quantity of oxygen be-

tween summer and winter equal to $.1155 = \frac{23}{200}$, or $\frac{1}{9}$ th nearly.

We here consider water as producing injury merely by displacing a certain proportion of oxygen, and not being prejudicial in itself, as is supposed by the generality of iron-masters. The reason given for its bad effects does not appear intitled to much weight. The opinion commonly entertained is, that the carburetted hydrogen set at liberty, carries off a greater quantity of heat than the nitrogen of atmospheric air. An effect which, if even true, is inadequate to explain the appearances. When the air is received into a water-regulator, as is the case in many blast-furnace works, a much larger quantity of moisture may be expected to enter the furnace, than with the ordinary apparatus. In the above calculation, if the air had been received over water, we should find that its temperature in the receiving vessel in winter and summer would be 50° and 100° . The vapour in the former amounts to 4.67 grains in a cubic foot: in the latter, to 18.95 grains in the same quantity.

Hence, air at 100° will contain less oxygen than that at 50° , by $.055$ of the whole; which is a little more than $\frac{1}{20}$ th. This added to the loss by increased temperature alone, will be $.159$, or nearly $\frac{1}{6}$ th.

We may from this conclude, that the extra-quantity of moisture admitted by using the water-regulator, will at any rate increase the difference in the amount of oxygen from $\frac{1}{6}$ th to $\frac{1}{3}$ th, or thereabouts; which, in all probability, will more than counter-balance the good effects arising from its uniform pressure. There does not appear to be, in the present state of our knowledge, any means of effectually remedying this evil. Some good might accrue from admitting the exterior air as cold as possible, and not allowing it to come in contact with water after entering the blowing-cylinder. This may be done to a certain degree, by causing

the air to ascend from a deep pit, by a pipe communicating with the blowing cylinder. This contrivance, however, should be laid aside whenever the air of the atmosphere becomes colder than the average temperature of the earth.

With regard to the defect arising from increase of volume of the air in the summer months, the heat caused by the friction of the blowing piston will be found to contribute much to the evil. The air by this means gets an additional elasticity, and if the same quantity of air be thrown into the furnace it must be effected by decreasing the pressure of the blast, or by increasing the aperture of the *nose-pipe*. If the compression of the air could be effected by any means which would avoid the friction of machinery, it would no doubt be a desideratum in the process of blowing. It will appear from these facts, that in summer, when the quantity of air is deficient from increase of volume, and from the presence of water, that a larger quantity of air should be made to enter the furnace, partly by increasing the velocity, and partly by using a *nose-pipe* of greater diameter. If the deficiency were made up by the increase of pressure only, the velocity would be too great for producing a maximum of combustion, where it is immediately wanted, independent of the mechanical evil it would be liable to produce. If, on the other hand, the aperture of the *nose-pipe* were increased in summer, to make the quantity equal to that of winter, the air would enter in a state of greater rarity, and the combustion would, from this cause, be of less intensity. This circumstance alone, perhaps, is sufficient to prevent a complete remedy of the evil, and will go far to explain the difference between the fractions resulting from calculation and experiment.

We shall conclude our account of this department of iron-manufacture with some general observations upon the nature and properties of pig-iron, as it is applied to different purposes.

When the iron has combined with its full dose of carbon, constituting what is called in the trade, grey, or smooth-faced iron, and also N° 1, it is admirably fitted for making the lighter and finer sort of castings, such as grates and other ornamental work. It is from iron of this quality that the cast-iron cutlery is manufactured, since no other would run sufficiently fluid for articles so small as the prongs of forks, and the bows or rings of scissers. This iron, however, is not the best for larger castings where strength and hardness are desirable; as in large wheels, for example, beams, pillars, railways, &c. The metal employed for these purposes contains a lesser proportion of carbon than the former, and is generally called melting-iron, or N° 2.

That species of pig-iron, however, which is combined with the smallest dose of any, is almost exclusively employed for making malleable iron, and is called, for that reason, *forge-pig*. We have given, in the next section, an account of the proportion of carbon present in the different varieties; and it will appear from thence, that of all the combinations of iron and carbon, steel contains the least, and grey, or N° 1, pig-iron, the most of any of the compounds we are yet acquainted with.

As a proof that pig-iron only requires to lose its carbon to become malleable, we have at present in this country manufactures upon a large scale, for converting cast metal goods, such as nails, cutlery, &c. into iron perfectly malleable, without even changing the figure given to them by casting. Nails produced in this way are so malleable, even when cold, as to bear the hammer, and are capable of being bent to a right angle in a *vice*.

But a still stronger proof that this metal assumed the form of iron is from the great heat it will bear. The

prongs of a common fork made by this process can be welded together with the greatest facility. Pig-iron, until lately, has been considered a much more complex body than experience has warranted. We have heard of its being supposed to contain filix, or, according to Mr. Davy, silicium, to which it owes some of its crude qualities. But the process just mentioned is sufficient to refute the assertion. Iron masters, even at this day, however, will talk about oxygenated pig-iron, meaning that which is least carbonated; but it must be clear to every one acquainted with the chemical qualities of those bodies, that the presence of carbon and oxygen in a liquid mass is perfectly impossible, as they are incapable of existing together uncombined at any such elevated temperature. Hence we must regard pig-metal as a compound of iron and carbon only. Manganese may perhaps sometimes be present in it, when particular ores are employed for smelting, but its union must be considered as accidental.

To make pure iron, therefore, we have, from these conclusions, only to extricate the carbon. This may be done, in small masses, by stratifying the articles in a close vessel with some substance containing oxygen. The poorer iron ores, which are free from sulphur, are used in powder for this purpose; and after the materials have been exposed to a heat just short of the fusion of the metal, the air being completely excluded, the carbon will become dissipated, and the iron left in a state of purity. See CASTING and FOUNDRY.

§ 4. Conversion of Pig-iron into malleable Iron, and Steel.

1. *Bar, or wrought Iron*—Iron, as obtained by the reduction of its ores in the blast-furnace, contains, as we have before stated, a certain proportion of carbon, which renders the metal unfit for the various purposes of forging, but constitutes its principal value as applicable to the use of the founder. To deprive it of this ingredient certain processes are gone through, the object of which is, by the concurrent action of heat and air, to dissipate the carbon under the form of an elastic compound. The kind of iron chosen for the conversion is that denominated by manufacturers *forge-pig*. It is the lowest quality made for the purposes of art; and, in consequence of its being combined with a smaller dose of carbon than any other, which thus causes it to bear a less price in the market, is doubly preferable for the end required.

The price of *pig-iron* is almost exclusively determined by the quantity of carbon which is in combination with it. The varieties usually distinguished are N° 1, otherwise called *grey*, *smooth-faced*, or *kissy*, metal; N° 2 and 3, and *forge-pig*. The proportion of carbonaceous matter present in these varieties is differently stated by different experimentalists. Clouet makes the highest proportion to amount to $\frac{1}{4}$ th; but from the results obtained by Mr. Muschet in combining iron *directly* with the doses of charcoal requisite to produce its various sub-carburets, $\frac{1}{7}$ th appeared to be the *maximum*. Of this, the following table, published by him in the 13th vol. of the Philosophical Magazine, will afford the necessary proof.

Soft cast-steel	-	-	-	-	-	-	$\frac{1}{12}$ th
Common ditto	-	-	-	-	-	-	$\frac{1}{10}$ th
Same, but harder	-	-	-	-	-	-	$\frac{1}{8}$ th
Ditto, too hard for drawing	-	-	-	-	-	-	$\frac{1}{6}$ th
White cast-iron (same as before called <i>forge pig</i>)	-	-	-	-	-	-	$\frac{1}{4}$ th
Mottled cast-iron (N° 2.)	-	-	-	-	-	-	$\frac{1}{3}$ th
Black cast-iron (N° 1.)	-	-	-	-	-	-	$\frac{1}{2}$ th

The first step in the process of decarbonization, according to the more common mode of operating, is to expose the iron in a

furnace, called by some a *refinery*, but by others, to distinguish it from one hereafter to be described, a *run-out furnace*. It consists of a vessel open at the top, imbedded in stone or brick work, about two feet three inches long, two feet wide, and ten inches deep. This is generally, in part, constructed of cast iron; and, when so made, has an outer case about two or three inches distant from the inner one, which is constantly supplied with a stream of cold water to prevent the apparatus from melting. The iron to be decarbonized is placed in this receptacle, and kept in a continual state of fusion for three or four hours by the aid of a coke fire, which is heaped to a considerable height above the level of the vessel, and extended proportionally on the hearth that surrounds it. The size of the hearth is mostly about three yards in length, and from two to three wide, and is completely covered by the funnel of the overhanging chimney. Bellows of considerable size are employed to carry on the process; and the current of air which issues from them is directed immediately on the surface of the iron by one or more *tuyeres*. These *tuyeres* are double, like the case, and continually cooled by the application of the same means. When the decarbonization is completed, the metal is let out at an opening in the side, which has been kept close during the operation by a *slopping* of sand. It flows into a groove about 18 inches wide, and six or seven feet long, constructed of stone in the floor that surrounds the furnace. The bottom of the vessel is so placed as to be nearly on a level with the floor; the only elevation given to it being what is merely sufficient to let the iron run out with facility. A considerable quantity of vitreous oxyd is formed during the process; and the loss in the weight of metal, which is stated to amount to from $\frac{1}{8}$ th to $\frac{1}{4}$ th, is principally referable to this circumstance. The total quantity of carbon which the iron contains originally is not estimated at more than $\frac{1}{4}$ th; and yet the approach of it to the pure state, or, in technical language, to the state of *bar* or *wrought-iron*, after this operation, is very inconsiderable.

The cake of metal procured by these means is broken into lumps of a convenient size, and subjected, in a furnace of another description, to a process known in the art by the name of *puddling*. The furnace, which is also distinguished by the same term, is a variety of the reverberatory; and at the immediate point where the flame strikes upon the hearth, a shallow concavity is worked out, in which the melted iron is exposed. Opposite to it is a door, and through this the metal is kept in continual agitation, by means of a sort of rake, for the purpose of exhibiting fresh surfaces perpetually to the influence of the air. Water is likewise occasionally thrown in, which in some degree contributes to the decarbonization. With the loss of carbon, the iron also loses its fusibility, and about the middle stage of the operation appears in the form of small detached lumps, which scarcely seem to exert any affinity for each other. At length, however, by much stirring, and frequently pressing them together, they cohere into a pulpy mass; and being gathered into pieces of a convenient size, are carried under rollers, where, after passing through four pairs, in succession, of a gradually diminishing gauge, they are produced into plates seven or eight inches wide, and three feet or more in length. Considerable quantities of matter are squeezed out in the rolling, which principally consist of a vitreous kind of oxyd. This is, for the most part, to be referred to the action carried on in the furnace; but some portion of it is, in all probability, created by the combustion of small pieces of fluid metal, which, engaged amongst the particles of the *puddled* mass, are hurled through the air in a state

of vivid inflammation, by the compressive violence of the rollers. The total loss thus sustained is estimated at from $\frac{1}{8}$ th to $\frac{1}{4}$ th. The plates obtained by this treatment have a very incompact appearance; and if attempted to be worked in the state they are then presented under, would crumble almost wholly into small granulated lumps. To impart to them the necessary closeness and solidity, they are again heated in another kind of furnace, and beaten forcibly with a heavy hammer, which is raised by machinery.

Previously to being thus treated, they are broken up into cakes of small size, and placed upon circular slabs of stone from 8 to 12 inches in diameter. The size of the cakes is in a great measure determined by a particular effect of the last pair of rollers that they are passed through: ribs, of a diamond shape, girding either one or both of them, on the whole extent of their surface, which leave a deep indentation on the plates, so as to render them easily frangible in that direction. The height to which these cakes are piled on the circular slab just spoken of, is generally about 12 inches; and when so prepared, they are placed on the hearth of a reverberatory furnace, which differs but little in form from that employed for *puddling*, except in being flat at the bottom instead of concave. The furnace is denominated a *balling furnace*; and the piles of metal, *pics* or *balls*. They are continued in this situation until they have arrived at a welding heat, and are then removed by large tongs under the stroke of the hammer. Near to the place a smith's forge is kept in blast, where long bars of iron are also urged to the welding point; and, after the first stroke or two of the hammer, united to the *balled* masses, to afford greater convenience in turning them. The masses are beaten out into ingots of about three feet in length; and the bar last mentioned being separated, they are divided deeply by an instrument termed a *fit*, to facilitate their being afterwards broken; and the process is then completed. They are in this state called *blooms*, and have yet to undergo another operation, for the purpose of being made into bars or plates. Much loss is sustained by the last treatment, and principally from the same formation of oxyd as was noticed in the preceding case. The quantity thus lost, added to the waste occasioned in the *bloomery*, which comes next to be described, is usually considered as equal to $\frac{1}{4}$ th of the metal obtained by *puddling*; which will make the total deficiency, by all the operations, as nearly equivalent to $\frac{1}{2}$. The ingots or *blooms*, which are received from the hammer, after being broken, over a small wedge-shaped block of iron called a *top*, are placed in a species of reverberatory, very similar to the *balling furnace*, and denominated a *blooming furnace*, or *bloomery*. They are here heated to welding, and then submitted to the requisite pressure under rollers, which are either plain or grooved, according as the iron is wished to be obtained in plates or in bars. This completes the whole of the processes necessary for making the best malleable iron; and it results from the observations which have been premised, that, in order to procure one ton of it, five-and-thirty hundred weight of *forge-pig* is previously required.

Two other modes of operating are at present in use; one of which omits the *puddling*, and the other, that part of the foregoing process that concerns the fabrication of *blooms*. In the former, iron is exposed to the heat of a charcoal fire, in a species of furnace precisely similar to the one before described as a *refinery*, or *run-out furnace*; and is continued in that situation, until the metal is thought to be sufficiently decarbonized. It is very frequently stirred during the operation; and when brought *into nature*, (to use the technical expression,) is collected into masses, and removed by

tongs under a large hammer, denominated, as applied to this particular use, a *stamping hammer*, where it is beaten into cakes, which are afterwards broken up, and treated in the *balling furnace* as before described. This is the old mode of working, and the iron obtained from it is by many conceived to be of very superior quality. The heat produced is considerably inferior to that afforded by coke in the *run-out furnace*; and the iron is less surrounded by the fuel than in the case just mentioned. The present charcoal fire is properly a *refinery*, and not the one which is used merely as a preliminary to the process of *puddling*. Here, the business of decarbonization is at once completed; and the resulting metal is in the same state of purity as that yielded from the rollers, after it has been *puddled* by the other method. *Balling* and *blooming* follow in regular succession, and plates or bars are produced exactly as before.

According to the second mode of treatment, in which *blooming* is omitted, the masses obtained from the *balling furnace* are reduced under the hammer into the form of solid, cubical blocks; and when their temperature is too much lowered to be capable of any farther working, they are again heated in a fire called a *chafery*, which is urged by a powerful pair of bellows, and scarcely differs from a common smith's forge, except in being larger, and the cokes upon it being heaped up to the unusual height of at least two feet. In this situation they are raised to the point of welding, and afterwards hammered out into ingots of a flattened shape. Iron bars are united to them very shortly after they are brought from the *balling furnace*, to afford a greater facility of management, in the same manner as was described in the making of *blooms*; and these, as before, are detached, when the ingot is sufficiently formed. The iron produced in this way is not considered so good as that afforded by either of the other processes, and is employed, for the most part, in the commoner services of art. Repeated rolling, or hammering, is the only means of imparting the fibrous texture so necessary to good bar iron; and as this treatment is less frequent in the present mode of operating, the deficiency of value in the material obtained may very probably be referable almost exclusively to this circumstance.

The above include the whole of the *important variations* that are presented in the manufacture of bar iron. Other shades of disagreement may be traced in different works; but they are of a nature too trifling and unimportant to merit any particular enumeration. The art is still in its infancy; and the light of chemical science, by being brought to a focus here, cannot fail to disclose many improvements in the present modes of procedure, which will greatly abridge the expence now incident to this valuable branch of national industry. That the mere abstraction of about 4 *per cent.* of carbon should require a sacrifice, in effecting it, of above 40 *per cent.* of iron, appears monstrous beyond example: and as those who are connected with the art become more scientific in their views, we shall unquestionably find that it will be much more economically accomplished.

When iron has been completely freed from carbon, and has acquired its highest degree of malleability by repeated hammerings, it is by far the most tenacious of all the metals, and is capable of being drawn into the finest wire.

The tenacity of iron, as well as of all the rest of the malleable metals, varies considerably according to its softness. After iron has been kept in a red heat for some time, and suffered gradually to cool, it becomes remarkably changed in point of softness. By being hammered, drawn into wire, or rolled, it increases in hardness to a certain extent; but, at the same time, partly loses its malleability.

By this mechanical treatment, when cold, its strength or tenacity increases; and it may be taken at one point, when it will require a far greater weight to break it, than if it were hammered either more or less.

All the experiments yet published relative to the tenacity of iron, and the other metals, are on this account very defective. The writer of this article has seen an iron wire, when newly annealed, break with a weight of 50 pounds; but, after being drawn through two holes of a wire plate, bear above twice that weight, without sustaining injury. Iron, when properly annealed, will bear more bending backwards and forwards before it breaks, than in any other state: but the strength, or that power which resists a weight, exerted longitudinally to break it, is jointly as the last property and its hardness. Hence the reason why its strength is increased with a certain degree of hammering. The specific gravity of malleable iron, according to Briffon, is 7.788; that of pig iron being 7.207. Iron, in a state of purity, requires so great a heat for its fusion, that the best crucibles are nearly ready to melt with it. It has, however, been fused, and cast into an ingot. It is said to liquify at 158° of Wedgewood. Its malleability is greatly increased by heat; and by raising it to a very high temperature, it becomes exceedingly soft, and may be brought so near to absolute contact with another piece similarly heated, that they unite firmly together. This process is called *welding*. Its great affinity for oxygen, when heated to a welding point, would very soon reduce it to an oxyd, if it were not for the vitreous matter fusing upon its surface; and it may be still more completely defended, by dipping it in powdered glass or sand. See *Description of Plates* at the end of the article.

2. *Steel*.—This substance, which is a compound of iron and carbon, but in less proportion than that of pig iron, is of such distinguished importance in most of the arts, that no other substance could be substituted, capable of supplying its united properties of hardness, tenacity, and elasticity. After the pig iron is totally deprived of carbon, and becomes malleable, the metal can be re-impregnated with that substance to a certain extent, without losing much of its malleable property.

It is curious to remark, that although we have made iron of excellent quality in this country, for all the nice purposes to which it is capable of being applied, yet, in attempting to convert it into steel, we have always failed; the steel being red-short, and otherwise bad. It, of late, however, has been so great a desideratum to obtain steel from British ore, in consequence of our want of communication with Sweden and Russia, that several efforts have been lately made to bring about this desirable object, and not altogether without success. We may yet entertain a hope, therefore, that the time will arrive, when we shall not be dependent on other countries for this useful commodity.

The only steel at present, on which perfect reliance can be placed, is made from some of the best marks of Swedish iron. The bars are stamped with certain letters or characters, well known to the steel-makers; and some of them have preserved their character for making good steel during a long series of years.

The size of the bars varies from 3 inches broad and $\frac{1}{2}$ inch thick, to about 2 broad by $\frac{1}{8}$ thick.

Nothing more is necessary to impregnate the bars of iron with carbon, by which they become steel, than to stratify them with powdered charcoal in a close vessel, called a *cementing pot*; exposing the same to a degree of heat as little short of what would fuse the steel as possible.

The furnace in which the process of cementing bar iron is performed is called a converting furnace.

The pots are made of a peculiar stone called fire-stone, from its joint property of not being liable to crack by the heat, and its little disposition to enter into fusion. It is a fine grit, and occurs abundantly in the neighbourhood of Sheffield. The interior of these pots is in dimensions from 12 to 15 feet long, and from 2 feet to 30 inches square. Every furnace contains two of them; and they generally hold about 5 tons of iron each. The metal is stratified with the charcoal dust, in such a way that each bar may be completely covered; and the last stratum, which should be thicker than the rest, is kept close with a mixture of clay and sand, so as to prevent the charcoal beneath it from entering into combustion with the outer air.

The fire is then gradually applied, and the exterior surface of the pots constantly enveloped with flame, till the whole mass has become of the heat required. This heat is kept up for a considerable time, so that from the commencement of firing to the maximum is about seven days. The same space is afterwards required to allow the mass to cool. This rule, however, is not sufficient to tell when the cementation is perfect. A hole is generally left in the front of the furnace, passing through the wall to the interior of the pot. One or two bars are laid with their ends projecting into the opening, which is loosely filled with powdered charcoal. When the process is supposed to have gone on long enough, one of these bars is drawn out and examined.

All bar iron must, owing to the manner in which it is made from the pig, contain a small portion of oxyd of iron, as well as some remains of iron not completely deprived of its carbon. The long continued heat which this process requires, cannot fail to cause an union between the oxygen and carbon, accidentally existing in the bars; and we may expect, in consequence, that an elastic fluid will be formed, which must be either carbonic acid or the carbonic oxyd; but since the oxyd is in the state of silvery cinder, we should rather conceive it to be the latter; and we believe experience warrants the conclusion.

This elastic fluid, when the metal is so near the fusing point, causes the surface of the bars to be covered with blisters, which are a sure sign that the cementation is complete: and it is from the number and size of these blisters, that the workmen know when to cease adding fuel to the furnace.

Steel is made of different degrees of hardness, by giving it more or less carbon; and this is effected by keeping up the heat a longer time, still having regard to the quantity and size of the blisters.

The steel used for coach-springs contains the smallest quantity of carbon; a somewhat greater proportion is required for table knives, forks, carpenters' tools, and agricultural implements; and the largest dose of all is wanted for files, which can scarcely be too hard, if the steel be sufficiently malleable to work.

Steel, in the state it comes from the cementing furnace, is called *blistered steel*, from the appearance we have just described. It is not used but for common purposes, although formerly we had no other kind. The bars of iron being formed under the forge hammer, and produced in a country not remarkable for the excellence of its machinery, the metal is found to abound with numerous seams and shells, which good workmanship might in a great measure avoid.

This evil is, however, very happily remedied, by making

the blistered-steel into what is called *shear-steel*, and *cast-steel*.

Shear-steel has derived its name from the advantage with which it has been applied in the manufacture of sheep-shears. Its admirable property of welding to iron, without the other qualities it possesses being injured, renders it of great importance in all cases where the body of the edge-tool is constructed of iron, and the edge merely steel.

From having been first made at Newcastle-upon-Tyne, it has also been called *Newcastle steel*. The apparatus used for its manufacture consists of a pair of bellows, or other blowing machine, and a fire place similar to that of a smith's hearth, but upon a larger scale. The hammer for drawing the bars is larger than a tilting hammer, but smaller than the one employed at an iron forge.

In order to make shear-steel, a number of bars of the best blistered-steel are laid together, and temporarily fastened. In this state they are introduced into the fire, and heated to a welding temperature; after which they are firmly united by means of the hammer, and drawn. At a second heat these masses are beaten down into bars about $1\frac{1}{2}$ inch broad and $\frac{3}{4}$ ths of an inch thick. By this process the loose parts and seams of the bars are closed together, and the steel is rendered susceptible of a polish, of which before it was not capable. But these are not the only advantages. The additional hammering so far improves its malleability, that the tenacity it enjoys is much greater, while its hardness is very little less.

This steel is particularly adapted for springs of every description, and for all edge-tools requiring great tenacity rather than hardness.

Cast-steel is entirely free from the mechanical defects which belong to blistered-steel, and even, in some degree, to shear-steel; since it consists of the latter variety completely fused, and cast into ingots.

The furnaces employed for this purpose should possess all the advantages which can be given to air-furnaces, on account of the great heat requisite for the process. (See FURNACE.) The crucibles, in which the steel is melted, are made of Stourbridge clay, mixed with a small quantity of powdered coke, which makes them less liable to crack in the heating or cooling; and, at the same time, gives to them a considerable degree of stiffness in the fire, when raised to the very great heat required. These crucibles are furnished with covers, which are of rather more fusible clay than the body of the vessel, and, on that account, are soon partially vitrified; by which means they become closely luted at the time the steel is at a temperature sufficiently high to be destroyed by the oxygen of the atmosphere.

The fuel employed for melting steel, consists of the hardest coxes, and in all cases where long continued and high temperatures are necessary, coxes of this description should always be employed. Two advantages attend the use of them; for although the soft coxes produce a very great heat during a short space, yet the length of time required for melting steel would oblige the workman to charge the furnace too often; so that he would ultimately get a greater heat by the permanence of the hard coke; and the specific gravity of the latter is so much greater than the soft, that the fuel is more condensed, and hence, allowing for the difference of cohesion, will give more concentrated heat, if the supply of air be sufficient.

The crucibles are of a size sufficient to hold about 30lbs. of steel; and, in general, each will bear charging three times, or even four: some would remain sound still longer than that, if the fires were continued; but they are seldom

kept in more than twelve hours in the day, and this will not allow of more than three heats. For the best possible cast-steel, the bars of the best blistered-steel are broken into small pieces, it being, on coming from the cementing furnace, sufficiently brittle for this purpose. An inferior kind of cast-steel is made from the scraps, which consist of the waste of the manufactories. The heat required to melt steel is very great; and inversely as the quantity of carbon combined with it. Before cast-steel making was brought to great perfection, the quantity of carbon given to it was greater, in order to effect its more easy fusion. The crucibles and furnaces, however, are now so much improved, that the steel can be melted with much less carbon, and it is, in consequence, so *kind*, to use a technical phrase, as to weld with iron, and even to be capable of uniting two pieces of it together.

After the steel has become sufficiently fluid, it is poured into cast-iron moulds, which form it into ingots of an octagonal shape; and are about 30 inches long, each weighing about 30lbs. Formerly, the great secret of making cast-steel was said to consist in using some peculiar flux. No substance, however, from what has been observed, can increase the fusibility of the steel, but an additional dose of carbon, which is improper after a certain quantity has been united with it. The only substance, therefore, which can be employed to any advantage, must be some fusible vitreous matter, capable of floating upon the surface of the metal, and defending it from the contact of air.

The flux at present used, and the most proper for this purpose, is the blast-furnace cinder. But pounded glass, or any vitreous substance which fuses a little before the metal melts, will answer equally well.

The ingots of cast-steel, as well as the bars of blistered-steel, and shear-steel, are drawn into rods ready for forging into various articles, by a piece of machinery called a *till*, or *tilting-mill*. (See *TILTING-MILL*.) By this hammer, the cast-steel can be drawn down to the size of $\frac{1}{2}$ inch square. But in reducing smaller than that, it would be liable to be injured in its fabric. It is drawn into rods of smaller size by hand, for the purpose of making gravers, and watch-makers' tools; and for still more delicate articles, it is manufactured into wire. The blistered-steel will not bear drawing to a small size, on account of the looseness of its texture.

Steel is of a mean specific gravity between wrought and pig-iron; and, like the former, it increases its property in this respect by hammering. Like iron, too, it becomes softer on being annealed, but never becomes so soft as that metal. When of good quality, and at a certain degree of hardness, it is stronger than iron; that is, when stretched longitudinally by a weight; but, by sudden bending or twisting, it is more liable to break short. In working it with the hammer, it will not bear so great a heat as iron; since the temperature iron and its combinations sustain without melting, is inversely as their dose of carbon.

This property of bearing heat, is, however, in a still less ratio in cast-steel. This is owing to its having entirely lost its fibrous form in the melting. Hence there is less danger in heating it after it has been hammered.

In welding steel to iron, or steel to steel, the fire ought to be very free from sulphur, or other extraneous matter; and the heated parts of the rods should be frequently supplied with either sand, or sand mixed with the scales which come from the hammered iron. This fuses upon the surface and keeps off the air. See *FORGE*.

The most singular property which belongs to steel, is that of its hardening by being heated red-hot, and cooling rapidly. This change is greater the hotter the steel, and the

colder the fluid into which it is plunged. (See *CUTLERY*.) Water, in general, is employed for this purpose; and spring-water is better than any other. If the water abound with animal or vegetable matter, the hot steel cools more slowly. This is occasioned by a film of the matter in solution forming and remaining upon the surface, and, being a bad conductor of heat, prevents the steel from cooling. File-makers say, that the salt which is inevitable in their hardening water, makes the steel harder, and they sometimes put sulphuric acid into it for the same purpose.

In hardening steel in thin plates, such as saws, particularly when of cast-steel, quenching in water would cause them to crack, and make them so hard as not to be useful. They have, in consequence, recourse to some substance which is not so good a conductor of heat. Oil, with tallow, bees' wax, and resin dissolved in it, is generally employed for these articles. (See the article *SAW*.) If the steel be heated red-hot, it mostly returns to its original state. This, however, is sometimes not the case with thin plates of cast-steel. In giving various degrees of heat from the hard state, it becomes more soft and less elastic. See *CUTLERY*.

This curious and valuable property which it possesses might, at first view, appear to be caused by an increase of density; but the specific gravity of hardened steel is less than before it is hardened. It has been said to depend upon a certain crystalline arrangement of its particles; but this is a mere apology for ignorance. The most plausible theory we have heard of is mentioned in one of Dr. Darwin's notes to his "*Botanic Garden*," and was the idea of a very ingenious friend of that celebrated author. This theory was equally applied to the singular property possessed by the glass toys known by the name of *Prince Rupert's Drops*. It is as follows. When the heated steel or glass is plunged into water, the exterior stratum becomes so hard and solid, as not to be capable of shrinking; and every succeeding layer is to a certain degree placed in the same situation. When caloric leaves a body slowly, it contracts in its dimensions, until it assumes something near its original volume. But if any force prevent the parts from approximating, the molecules will attract each other with a power equal to the repellent energy of the caloric that caused the expansion. So soon, however, as the outer stratum is broken, the whole of the others are destroyed in succession. This is most glaringly the case with the glass drops before spoken of, and, to a certain extent, with unannealed glass, and hardened steel.

With respect to the latter, however, it is confined to large masses, and particularly of cast-steel. The rollers employed by jewellers and others are of cast-steel, and are very liable to break in the hardening, although about half the mass in the middle is pure iron. They do not always crack at the time, but at different periods afterwards, and frequently, when no violence is applied to them, some have been known to fly six months after being finished. Sometimes they break with great report, and what strengthens the above opinion as to the cause is, that the figure of the roller is frequently changed from a round to an elliptical shape. For farther particulars, see *STEEL*.

§ 5. Chemical Properties.

When a piece of polished iron is exposed to the air, it soon loses its lustre; and if the atmosphere be humid, it becomes covered with red spots called *rust*. When it is exposed at 400 degrees of Fahrenheit, it changes to a yellow colour. The temperature being increased, the colour gradually turns to a brown, and at the heat of about 600° it becomes of a beautiful blue tint. This change of colour arises from the combination of oxygen;

the quantity increasing with the temperature. If the surface be defended by a coating of chalk and a solution of glue, no change of colour takes place when the heat is applied. In the art of blueing steel, advantage is taken of this method to make the blue ornamental.

In a higher temperature the surface becomes covered with a scaly crust, which is composed of oxygen and iron; and in the heat of a smith's forge, it combines with oxygen so rapidly as to burn, throwing off sparks in bright corruscations. If small iron wire be exposed in pure oxygen gas, the end being ignited with a bit of greased cotton, the metal enters into brilliant combustion, and a globule of melted matter is formed at the end of it. The iron so burnt loses all its metallic properties, by combining with the oxygen; and during this change the phenomena of burning take place. The globule is so brittle as to be capable of being reduced to powder, and is called the black or vitreous oxyd of iron.

Iron has so great an attraction for oxygen, that it decomposes water even in the cold. When filings of that metal are mixed with water in a vessel connected with a pneumatic apparatus, an elastic fluid is evolved, which is found to be hydrogen. The iron loses its metallic lustre, and ultimately is converted into the black oxyd before spoken of.

If this mixture be in a retort, and the boiling heat applied, the iron combines with the oxygen of the water with much greater rapidity; and, of course, a much greater quantity of hydrogen is eliminated. This method has been employed to obtain the black oxyd of iron, which was formerly called *Martial Ethiops*. Iron decomposes water with very great rapidity, when the sulphuric or muriatic acid is present. The acid takes up the oxyd as it is formed by the agency of the water, and a new surface is constantly presented. A large quantity of hydrogen is in this process disengaged, and it is by the present method that this gas is procured for filling ærostatic machines, and for other purposes. If the oxyd which is taken up by the acid be precipitated by an alkali, and dried instantly, it will exhibit a similar appearance to that obtained by the action of water alone. When first separated it has a green appearance, which it owes to the presence of water; and this being dissipated by heat, it is left of a dark-grey colour. This oxyd, formed by either of the above processes, is called the prot-oxyd of iron, because it is combined with the *first* or smallest dose of oxygen. According to Proust and Lavoisier, it consists of 73 of iron, and 27 of oxygen.

If the prot-oxyd of iron be exposed to the air in a red heat for a length of time, it assumes a red colour, and constitutes the substance known in the arts by the names *crocus* and *colcothar*. This change of colour is found to have been caused by its combining with an additional dose of oxygen, and the product is denominated the peroxyd, consisting, according to Proust, of 53 iron, and 48 oxygen. From the best chemical authorities, it appears that iron unites with oxygen only in two fixed proportions, constituting the prot-oxyd and the peroxyd; although it has been held by some that there are more varieties.

If a bar of iron be heated red-hot, and a stick of sulphur applied to it, a fluid substance will drop from its end, which is found to be compounded of sulphur and iron, and in chemistry is called sulphuret of iron. The fusion of sulphur and iron-filings, in a crucible, gives a similar product. The attraction between these substances is so great, that their union in nature is very common.

Iron-filings, mixed with sulphur, and made into a paste with water, in a certain time become very hot and even produce flame. The mixture is sometimes buried under ground to produce an artificial volcano. This phenomenon, how-

ever, does not depend upon the immediate combination of the sulphur with the iron. The water, which is a considerable agent, is decomposed; the oxygen uniting with the iron to form an oxyd of iron, and with the sulphur to form the sulphuric acid, while the hydrogen combines with another portion of the sulphur producing sulphuretted hydrogen, which occasions the flame in the experiment.

When iron-filings are heated with sulphur, even where oxygen is not present, at a little short of the temperature of redness, they combine and produce flame. We are indebted to the associated Dutch chemists for this fact, as well as a similar experiment with sulphur and copper.

The artificial compound of sulphur and iron, from the experiments of Proust, is composed of 62.5 sulphur

37.5 iron

100

The native sulphuret is found to contain a greater proportion of sulphur. When heated in a close vessel, some of the sulphur sublimes, and may be collected in a proper apparatus. By this treatment, it is reduced to the state of common sulphuret, and loses 20 per cent. of its weight. It is hence composed of 50.6 sulphur

49.4 iron

100

According to some experiments made by Mr. Hatchett, however, these proportions are not regular in specimens where the crystalline form varies. This ingenious chemist has found a native species agreeing in the proportion of its constituents with the artificial sulphuret. It is what has been called magnetic pyrites; and is by this test of the magnet distinguished from the common pyrites, which does not possess that property. It has also another peculiar character. If dilute sulphuric or muriatic acid be poured upon it, a rapid action takes place, and sulphuretted hydrogen is evolved. This is not the case with the super-sulphuret till it has been exposed to heat, when it loses its excess of sulphur. The common sulphuret of iron has been employed to make artificial magnets. Mr. Hatchett found that not only the sulphurets, phosphurets, and carburets, were separately magnetic; but suspects that certain proportions of all these may constitute a *maximum* of magnetic virtue.

It is highly probable, that the iron is the only substance possessing magnetism; and that the facility with which these compound substances become magnetic, may arise from the greater ease with which the particles of iron assume the peculiar arrangement on which this curious property depends. That some arrangement, though perhaps equally mysterious with crystallization, may be the cause of magnetism, there is much reason to believe. By mixing iron-filings with melted resin, and inclosing them in a brass tube, if a magnet be brought near to the tube, while the mass is still liquid, the whole, when cold, will become a magnet. During the touching of a piece of steel to make it magnetic, there is little doubt but that a new and peculiar disposition takes place amongst the particles, notwithstanding the solid state of the metal. The particles of bodies appear to be free to motion in the solid form. We find that iron combines with carbon, while both bodies are in that state; and what is still more curious, the compound assumes a different crystalline structure, according to the proportions of the two bodies. Oxygen appears, in some instances, to alter the internal arrangement of solid bodies. If brass, for example, were to be kept in a damp room, but more particularly where the fun-

of acids are present, the metal, although previously very tenacious and ductile, becomes so brittle, as not to bear bending to a right angle; at the same time that the broken surfaces exhibit a crystalline fracture. That species of form, therefore, under which magnetism exists, may be brought about by various means. All iron instruments, kept in one position for a length of time, become magnetic; especially if that position coincide with the magnetic meridian. We regret that so little is known on this interesting subject; and for farther particulars refer to the article **MAGNETISM**.

Iron combines with several of the metals forming alloys, none of which have very striking or useful properties. The alloy of iron and gold has been examined by Mr. Hatchett, who found that 11 parts of gold to 1 of iron formed a malleable alloy, remarkably ductile, so as to roll into plates, and be capable of being stamped into coin. The colour was of a pale yellowish-grey, and it was of the specific gravity of 16.885. The most singular property of this alloy is its increase of volume by combination. Before the union, the bulk was 2799; and afterwards, 2843. The very contrary is the case with most of the other alloys of metals, and agreeably to Berthollet's doctrine of affinity, we find that the mean specific gravity of bodies by experiment, is greater than the arithmetical mean, directly as the affinity of the bodies. We should, therefore, in this instance conclude, that either the affinity of the metals is trifling, or that the above law is not general.

The alloy of pure iron with platina has not been effected from the great infusibility of the two metals. Dr. Lewis alloyed cast iron with platina, as well as steel. The specific gravity of this alloy, contrary to the last, was greater than the arithmetical mean. It was very hard and tenacious, possessing some degree of ductility.

After being kept ten years, it was little tarnished. Iron is easily alloyed with silver. In equal parts they form a compound of considerable ductility, of the colour of the latter metal, but much harder; and is attracted by the magnet. The metals separate, in some degree, when kept in fusion; but, according to the experiments of Morveau, not completely; the silver retaining some of the iron, and the iron some of the silver, by which its quality, as a metal, is much improved. Iron is not easily combined with copper in large quantity. We find, however, that these metals are capable of uniting, and the alloy is, in some degree, magnetic. Indeed, in forming certain instruments of brass, where the magnetic needle is employed, they are frequently defective from this circumstance. To free copper entirely from iron, it should be redissolved in an acid. The oxyd, after precipitation, should be dissolved in aqua ammonia, and the alkali then distilled from it. This being afterwards treated in a close vessel with some inflammable matter, the metal will be obtained pure. The alloys of tin and iron, and that of iron with zinc, may be formed by mixing clean iron-filings, or turnings, with those metals while in a state of fusion. These compounds are not of any use. Iron may be soldered with several of the metals. Copper, gold, and silver, unite to it with great facility; but require the presence of borax to keep off the air.

The most permanent solder for iron is the carburet of the same metal, called N^o 1, pig-iron. The pig-iron loses some of its brittleness, and the malleable metal becomes much harder. It does not appear improbable that steel might be formed by uniting these two substances together in certain proportions.

We have next to treat of the salts of iron, or its combinations with acids.

Sulphat of Iron.—Sulphuric acid does not combine with iron in its metallic form; in conformity with the general law that no acid unites with a metal till the latter is previously oxydated. Iron is but slightly acted upon by this acid in the cold; but with a degree of heat far short of boiling, the iron takes from it a portion of oxygen, converting it into the sulphurous acid, which escapes in the form of gas. The iron, thus oxydized, combines with another portion, and forms the sulphat of iron.

When water is added to the iron and the acid, a much more rapid action takes place. The metal seizes the oxygen of the water; hydrogen is evolved; and the acid unites with the oxyd forming the salt in question. When the product obtained by this means is more than the water can dissolve, it assumes the form of green crystals, which, when separated, are the same with those known in commerce and the arts by the names of *green vitriol* and *copperas*.

In the action of iron upon the concentrated sulphuric acid, it appears anomalous, that the metal should not be oxydized with more facility by this acid, when water is so rapidly decomposed, the elements of which have so strong an attraction for each other. It may appear equally strange that the water is not decomposed when the acid is not present. When it is recollected, however, that the oxyd of iron is not soluble in water, nor sulphat of iron in the acid, it will appear very clear that the two substances are both essential to the effect; the acid promoting the decomposition of the water by taking away the oxyd, and the water taking up the salt, which would be equally obstructive to the process.

This salt is not commonly obtained by the above process. The sulphuret of iron, above described, already consists of two of its elements, namely, sulphur and iron; the oxygen and water of crystallization being alone wanting to complete the salt under inquiry. For this purpose, the natural combination of it, or pyrites, is first roasted, and then exposed in large heaps under sheds. These heaps are frequently moistened with water, by which, together with the presence of the air, the iron and the sulphur become oxygenated, and crystals of the sulphat begin to form. The water, which is thrown on from time to time, dissolves the salt, and runs into large reservoirs, which are also under sheds, to prevent the rain falling into them. This solution, however, does not contain the salt in a fit state for crystallization, being too highly charged with oxygen. The liquor is transferred into large boilers, and pieces of old iron put into it, which, by taking up the excess of oxygen, change the solution from a red to a green colour. When the evaporation has gone on to a certain point, the salt crystallizes, and the green crystals being separated, are fit for sale.

When the crystals are obtained from a clear solution, and are well defined, exhibiting transparent rhomboidal prisms, the specific gravity of which is 1.8, the salt may be deemed in a state of purity. It dissolves in 13 its weight of boiling water, and twice its weight of water at 60°. When kept dry, it is not liable to change in the air; but if moistened it becomes covered with red spots by the absorption of oxygen, and if it be dissolved in water, it returns to the state in which it existed before boiling with the metallic iron. When the crystals are heated, the salt at first fuses, then assumes the form of white powder, by losing its water of crystallization. At a red heat the acid begins to fly off; and ultimately a fine red oxyd is left behind. It is in this way the *crocus* of commerce is prepared.

According to the analysis of Bergmann, this salt is composed of

Acid -	39
Protoxyd of iron	23
Water -	38
	<hr/>
	100

According to Kirwan :

Acid	26
Oxyd .	28
Water .	46
	<hr/>
	100

It is decomposed by the alkalis and alkaline earths ; and by all the salts forming insoluble compounds with sulphuric acid.

Oxy-sulphat of Iron.—This salt consists of the sulphuric acid united to the peroxyd of iron. Its solution in water is of a deep reddish-brown colour. It is insusceptible of crystallization. Hence, the green crystals separated in making copperas are perfectly distinct in their nature from the salt which is left in the remaining liquid. When the sulphat is exposed in a state of solution for a length of time, it assumes a red colour, and is converted into this salt ; so that we never find the common sulphat in mineral waters, but the oxy-sulphat. This change may be more speedily brought about by heating it with nitric acid. A quantity of nitrous gas is evolved, and, according to Mr. Davy, ammonia also ; the former from the decomposition of the acid, the latter from the decomposition of both the acid and the water. The fluid gradually assumes a deep brown colour. It has a strong astringent taste, much resembling the juice of sloes. When this salt is formed without the addition of water, it is exceedingly heavy, and concentrated, and of a deep brown tint, approaching to blackness. If concentrated sulphuric acid be poured into it suddenly, it loses its brown colour, and becomes of a clear white, having the consistence of thick cream. It is so soluble in water, that when evaporated slowly, instead of crystallizing, it assumes the form of syrup. If too much heat be applied, however, the oxyd either precipitates, or it assumes the form of a sub-salt, and becomes insoluble.

Since the oxy-sulphat differs from the sulphat in the proportion of oxygen only, several substances reconvert it into that salt, by abstracting the excess of oxygen. If it be kept, for instance, for some time in a close-stopped bottle with iron-filings, the metal becomes oxydized, and the whole is changed to the simple sulphat.

Gay-Lussac has lately shewn that the quantity of acid in any metallic salt is in proportion to the quantity of oxygen in the metal. (*Memoires d'Arcueil*, t. ii p. 159.) Hence no additional acid is required in converting this salt into the sulphat.

Tin, and several other metals, produce the same effect. The excess of oxygen may instantly be taken away by passing sulphuretted hydrogen gas through the oxy-sulphat. This gas reduces the oxyd exactly to a *minimum* of oxydation, to the state of protoxyd ; and hence the reason why this gas does not precipitate iron from its solutions.

The oxy-sulphat may be easily separated from the sulphat ; the former being soluble in alcohol, which the latter is not.

From the method required to form this oxy-salt, it will appear that there are several substances which may be employed to give their oxygen to the sulphat of iron. Of these are the nitric and oxy-muriatic acids. And by pouring a

solution of gold into a solution of this sulphat, the oxy-sulphat is produced, and the gold becomes metallic.

Dr. Thomson enumerates several *triple salts*, formed by the sulphuric acid with iron and other metals.

1. Sulphat of iron and copper.
2. Sulphat of iron and zinc.
3. Sulphat of iron and nickel.

The former of these sometimes exists in the blue vitriol of commerce, which is a very great evil to colour-makers. The iron precipitates with the copper, and destroys the beauty of the latter. In order to ascertain whether iron be present in blue vitriol, dissolve a small quantity in a wine-glass, and add aqua ammonia till it smells strong of the latter. The oxyd of copper will be dissolved, and the oxyd of iron left at the bottom. By standing for some time, the precipitate becomes yellow and very conspicuous. It is even said that some of these salts have triple bases. The two hitherto observed are as follows :

1. Sulphat of iron, zinc, and nickel.
2. Sulphat of iron, copper, and nickel.

Sulphite of Iron.—Berthollet has given us an account of a compound of iron with the sulphurous acid. When iron is exposed to the action of this acid, it becomes speedily oxydized ; but what is singular, not at the expense of the water, as is the case with the sulphuric acid ; but it appears that the acid is decomposed, the oxygen uniting with the iron, while the sulphur combines with the salt. Hence this sulphat of iron is always contaminated with sulphur. The sulphurous acid has a less affinity for iron than the sulphuric ; and if the latter be added to the sulphat, its acid is disengaged in the form of gas.

Nitrat of Iron.—The nitric acid has very violent action upon iron, and an abundance of the red fumes of nitric oxyd are disengaged. The same thing in some measure takes place with this acid, as has been remarked with regard to the sulphuric. If it be more than a certain strength the action is feeble, until a certain portion of water is added. The same explanation will answer in both instances. The nitric acid does not dissolve the nitrat at first formed, the presence of which interrupts the future progress of the operation. When the solution is made with much water the iron is oxydized to a *minimum*, and the salt formed is the proper nitrat. It is of a pale green colour. The vessel in which this solution is made should be kept in water as cold as possible, else it will absorb too much oxygen, and pass to the oxy-nitrat.

Oxy-nitrat of Iron.—When iron is acted upon by the less diluted acid, and with heat, the salt formed is the oxy-nitrat. The solution is of a deep brown, resembling the oxy-sulphat. It has a strong astringent taste, and turns vegetable blues red. When the solution is boiled the oxyd is partially precipitated ; nor will it afterwards dissolve in the nitric acid. This has furnished one means of separating iron from other substances in the analysis of minerals.

We are indebted to Vauquelin for a method of obtaining this salt in a crystallized state. The method he recommends, is to keep the black oxyd of iron and strong nitric acid together for a length of time, till the crystals appear. They have an acid taste, and are deliquescent. The form of them is that of a four-sided prism.

The alkalis precipitate the oxyd of iron from this salt of a fine yellow colour, and yield a product which is valuable to painters.

Muriat of Iron.—The muriatic acid, like the sulphuric and nitric, acts feebly upon iron, except it be diluted to a certain extent with water. It differs from the latter, and

agrees with the former, in not being decomposed; but merely takes up the oxyd formed by the oxygen of the water, the hydrogen being given out in the state of gas. The solution is of a green colour; and, on evaporation, it affords crystals presenting the same appearance. Mr. Davy has given us several useful facts relative to this salt. It was employed by him to great advantage in making some eudiometrical experiments. He found that a solution of it absorbs a large quantity of the nitric oxyd gas, which, in this situation, is better fitted for absorbing oxygen than by mixing the two gases together. By absorbing this gas it assumes a brown colour, and acquires an astringent taste. When the compound is heated, it appears that the gas is decomposed as well as a portion of water; since the iron becomes more highly oxydized, and ammonia is formed. Mr. Davy recommends an infallible method of forming this salt, by adding muriatic acid to sulphuret of iron. The sulphuretted hydrogen prevents the muriat from becoming oxy-muriat, which has not the property of absorbing the nitric oxyd. Muriat of iron is very soluble in water and in alcohol. It is decomposed by the alkalis and alkaline earths, and all salts, the bases of which form insoluble compounds with muriatic acid; such as silver and mercury.

Oxy-muriat of Iron.—The muriat of iron, like the sulphat and nitrat, is converted into the oxy-muriat by the oxyd of iron passing from the state of prot-oxyd to that of per-oxyd. It slowly undergoes this change by exposure to the air; and rapidly, by the agency of those bodies which afford oxygen with greater facility, as the nitric and oxy-muriatic acids. The solution is of a deep brown, but does not afford crystals by evaporation. It has a powerful, astringent taste, and a peculiar odour. When this salt is distilled it affords oxy-muriatic acid, leaving in the retort the prot-oxyd of iron.

If the heat be applied rapidly, the salt sublimes; not in the state of oxy-muriat, but of muriat of iron.

There is also a triple salt formed by the muriatic acid with iron and ammonia. This may be prepared by adding iron-filings to muriat of ammonia. It may either be obtained in crystals by evaporation, or it may be sublimed. In the latter state it is known in medicine by the name of *Fluxus Martis*.

Phosphat of Iron.—The phosphoric acid has little action upon iron; but the acid unites with the prot-oxyd, and forms this compound.

It is prepared by adding a solution of sulphat of iron to a fluid mixture of phosphat of potash. The salt precipitates in the form of a blue powder, which is insoluble in water, and does not lose its colour by exposure to the air.

The substance known by the name of native Prussian blue, is a phosphat of iron; but, what is remarkable, it has little colour when dug out of the earth, becoming deeper on exposure to the atmosphere. A crystallized specimen, lately brought from Brazil, has been analysed by Vauquelin, and is composed of

Acid	21
Protoxyd	45
Water	34
	<hr/>
	100

Oxy-phosphat of Iron.—This salt is formed by taking advantage of some oxy-salt of iron and phosphat that is soluble; as, for instance, by adding together the oxy-sulphat, or oxy-muriat of iron, and the phosphat of soda or of potash, a white powder will be precipitated, which is the oxy-phosphat of iron.

This salt is insoluble in water, but dissolves in the muriatic or sulphuric acids; from which it may be precipitated, unchanged, by pure ammonia.

Sub-oxy-phosphat of Iron.—The salt above described is not decomposed by the alkalis like the metallic salts in general. The alkali combines with a portion of the acid only, leaving the salt with an excess of base, which is the sub-oxy-phosphat of iron. This sub-oxy-phosphat does not dissolve in water, or scarcely in acid; but it has the singular property of dissolving in albumen, or the white of eggs; and if an alkali be present, which is the case with the albumen in the serum of blood, it assumes a reddish-brown colour, and is supposed, therefore, to be the principal colouring matter of the red blood of animals.

Fluat of Iron.—The liquid fluoric acid attacks iron, or rather takes its oxyd, which is formed by the oxygen of the water, while hydrogen gas is evolved. It has no striking properties, or any which it may be important to describe.

Borat of Iron.—This salt, being insoluble in water, is obtained by mixing solutions of borat of soda and sulphat of iron together. It appears in the form of a yellowish powder, and melts into glass before the blow-pipe.

If the oxy-sulphat of iron be employed, an oxy-borat will be obtained.

Carbonat of Iron.—When iron-filings are mixed with the liquid carbonic acid, and suffered to remain for some time, the water will acquire a perceptible taste of iron. If it be exposed to the air, a precipitation takes place, either from the gas flying off, or from the salt assuming the state of sub-carbonat. The precipitate is of a yellow colour. This salt is frequently found in mineral waters, to which it gives a peculiar odour. The water, by standing a little while, is not sensible to any of the tests of iron; but a yellow precipitate is found at the bottom of the vessel.

When a solution of neutral carbonat of potash is added to a solution of sulphat of iron, a large quantity of iron is dissolved by the carbonic acid, giving to the fluid a strong inky taste.

This salt is also found native in the solid form, of which we have already spoken in the mineralogical part of this article.

The common rust of iron, formed by exposing iron to the air, may be proved to be a carbonat of this metal by its effervescence with acids. It is, no doubt, from the solubility of this salt, that iron becomes so perishable by exposure to the weather.

The sub carbonat of this species, according to Bergmann, is composed of

24 acid
76 oxyd
<hr/>
100

It appears from some experiments of Bucholz, that the native carbonat, by heating red-hot, becomes magnetic.

Acetat of Iron.—The acetic acid, when of moderate strength, added to iron-filings, causes the iron to be oxydized by the decomposition of the water, while the hydrogen is set at liberty. The solution has a sweetish, though inky taste, and emits the odour of vinegar. The best way of forming this salt is by mixing acetat of lead and sulphat of iron together. The sulphat of lead becomes insoluble, and the acetat of iron remains in the liquid. Mr. Davy obtained this salt by digesting the sulphuret of iron with acetic acid. It afforded to him crystals in small prisms.

Oxy-acetat of Iron.—If the oxy-sulphat of iron be used instead of the sulphat with the acetat of lead, the sulphat

of lead is precipitated, and an oxy-acetat is held in solution of a beautiful reddish-brown colour. This salt does not afford crystals. It has the smell of vinegar; and, when in solution, affords an excellent test for arsenic. The arsenic forms an insoluble compound with the iron, of a brilliant orange tint. The pyrolignic acid, which is an impure acetic acid, unites with iron, and yields a very cheap acetat of iron, which is used by dyers and calico printers as a mordant.

Succinat of Iron—When the solutions of succinat of potash or soda, and sulphat of iron are mixed together, a brownish-red insoluble precipitate is formed, which is the succinat of iron. The soluble succinat may hence be employed to separate iron from other substances.

It is composed of

Acid and water	61.5
Oxyd - - -	38.5

100

The *ovalat*, *tartarat*, *citrat*, *malat*, *benzoat*, and *suberat* of iron, are but little known. They are all, however, soluble in water.

Gallat of Iron.—When the gallic acid is added to any solution of iron, the oxyd being at a *minimum* of oxydation, a fine purple precipitate will be produced. If the acid be entirely freed from tan, the purple colour is much more conspicuous. The pure gallic acid, therefore, is much better as a test for iron, than the mere infusion of galls.

The tan may be separated from this acid by means of gelatine, which does not precipitate the gallic acid. By this treatment a solution may be obtained colourless and limpid.

If the gallic acid be added to a salt of iron, in which the oxygen is at a *maximum*, the precipitate is a very complete black; but the oxyd soon separates, and falls to the bottom in the form of a red powder. This property renders these salts of iron unfit for making writing ink. When the oxyd is in the state of prot oxyd, the combination is permanent; and although it is not so black when first used, it soon becomes dark by exposure to the air. We may hence learn, that while ink is in use, it should not be kept exposed to air; since it passes to the state of oxy-gallat, and the oxyd will fall down.

Prussiat of Iron.—When the triple prussiat of potash and iron is poured into a solution of the latter substance, the oxyd being at a *minimum* of oxydation, a white powder is precipitated, which is the prussiat of iron. If this powder be exposed to the air, it changes to a blue; and in this state is called the oxy-prussiat of iron.

Oxy-prussiat of Iron.—This salt is formed by the same soluble prussiat being added to the oxy-sulphat of iron, and constitutes the beautiful blue pigment, known by the name of *Prussian blue*. It is generally, however, adulterated with alumine. See PRUSSIAN BLUE and PRUSSIC ACID.

Arseniat of Iron.—The native arseniat has been already described in the mineralogical part of this article. Arseniat of potash, or ammonia, being added to the sulphat of iron, an insoluble powder precipitates, which is the artificial arseniat of iron.

Oxy-arseniat of Iron.—The arseniat of iron, in common with all the other salts of this metal, combines with an extra dose of oxygen, constituting the oxy-arseniat. The precipitate formed by the arsenic acid and the oxy-acetat of iron is of a blueish-white colour.

The oxy-arseniat of iron, from the analysis of Chenevix, is composed of

Acid	42.4
Oxyd	37.2
Water	20.4

100

Arsenite of Iron.—The arsenious acid, or the common white arsenic of commerce, forms with iron peculiar compounds, which have been but little examined. It does not take the oxyd of iron from the sulphat, but decomposes the acetat, forming with the protoxyd a substance of a greenish-yellow colour; the precipitate from the oxy-acetat being of a bright orange. If either of the acetats contain the least portion of the sulphat of iron, it prevents the precipitation of the arsenite.

Chromat of Iron.—See CHROME.

Most of the other acids combine with iron; but they form compounds which are but little known. Certain alkaline salts act upon iron, and produce triple compounds, which have not received a particular examination. When the nitrat of potash is fused in contact with that metal, the acid is decomposed, and the iron oxydized to a *maximum*. This melted mass, after the acid is completely dissipated, is of a red colour. If, before it becomes deliquescent, which takes place from the presence of the alkali, it be thrown into water, the alkali dissolves a quantity of iron, forming a solution of a deep splendid purple tint. The colour remains permanent for some time, if the air be excluded; but, if exposed in an open vessel, it changes quickly to a green, and the oxyd ultimately precipitates, leaving the liquid clear and colourless. The precipitated oxyd is of a deep red colour.

Description of Plates.

Plate I. fig. 1, a plan of an iron forge; *fig. 2*, an elevation of the same. In *fig. 1*. A is a water-wheel, which gives motion to the stamping hammer E; G, the mill-dam; H, the tail water course; I is a small water-wheel, to give motion to the blowing machinery; L, *fig. 1*, is another water-wheel, which works the hammer O, for drawing the balls, &c. into bars; K is the mill-dam for supplying all the wheels.

Q, in *fig. 1*, is a refinery, technically called a *finery*; in *fig. 2*. is the elevation. It is blown by the double blowing cylinders, c, c. R, the *chafery* for heating the masses of iron a second time after hammering; S, S, plans of balling furnaces, and similar to the puddling furnace.

Plate II. fig. 1. is a front view of the finery, as seen *fig. 2. Plate I.*; *fig. 2*. being a side view. K, the hearth on which the pig-iron and charcoal is placed; G H, the chimney; f, the air-pipe; g, a cock to regulate the blast; b, a leathern pipe connecting the main-pipe with the nose-pipe; i, *fig. 3*, an enlarged view of the tuyere-iron, into which the nose-pipe i is inserted, and which enters the hearth at a, *fig. 1.*; m and n are two iron pipes, terminating in, and forming a part of the tuyere-iron. The pipe m communicates with a cistern of water, which conveys a stream of cold water, for the purpose of keeping the tuyere-iron cool, and which is discharged at n, into the cistern o, *fig. 4*, where the whole of this apparatus is seen. The furnace called the *run-out furnace* is very similar to the finery. The hearth of the finery is surrounded with cast-metal plates, having a cavity under the bottom plate, to throw water from time to time to keep the bottom plate cool. The *run-out furnace* differs from this, in being surrounded on three sides with water. This furnace, and its use, has already been described. The chafery is also similar to the

finery, except in the hearth being more like the smith's forge.

Fig. 5. exhibits tongs for taking the balls from the furnace to the hammer; and *fig. 7.* an iron ladle, employed to throw water into the puddling furnace, to oxydate the iron.

Fig. 8. the face of the stamping hammer, which is made to be taken out occasionally.

Fig. 9. the face of the hammer employed for drawing out the bars: *b* is the part used to extend the bars in length with more expedition; the part *a* being employed for smoothening or finishing the bar.

Figs. 10. and 11. are different views of the balling furnace: *a* is the fire-grate; *b*, the hole where the fuel is admitted; *d d*, the roof made of fire-brick; *e*, the door through which the balls are admitted; and *b b*, the hearth on which the balls are laid to be heated, by the flame which is carried by the draught of the chimney *G*. This furnace is bound on all sides by bars of iron, secured by bolts.

The puddling furnace is so nearly similar to this, as not to require a separate drawing. The hearth is more concave opposite the door, for the purpose of containing the metal which is liquid, previous to its assuming its malleable state. The door of this furnace, for heating the balls, consists of a frame of wrought iron, containing fire-bricks, to prevent the escape of heat. It shuts and opens upon the hole, by being attached to the end of a lever; its weight being counterpoised at the other end. See *fig. 1. Plate IV.* where *R* is the lever; *l*, the door; and *f*, the part by which it is raised.

The door of the puddling furnace consists of a solid piece of cast-iron, about 3 inches thick, having a small hole through it, for the purpose of inspecting the process, and introducing the puddling instruments.

Plate III. figs. 1. and 7. are views of the reverberatory furnace, used by the cast-iron founders, for melting large quantities of metal at once. This furnace, like the last, is heated with flame from its fire place *a*, the fuel being introduced at *B*; *c d* is a sloping hearth, on which the pigs or other pieces of metal are laid; *b*, the door where it is introduced; and *g*, the chimney. The melted metal runs down to the part *e*, where it is accumulated, and is let out at *f*; or a door may be opened at *e* above, and the melted metal carried out in ladles, to be poured into the moulds.

Fig. 2. is a section of a cupola, in which *a* is the interior of the furnace containing the metal and cokes; *e*, the tap hole; *b*, the nose-pipe; *d*, a leathern pipe connecting the air-pipe, which comes from the blowing cylinder, with the same; *e*, a stop-cock to regulate or turn off the blast.

It generally consists of four plates of cast-iron, firmly bolted together; the interior being lined with fire-brick. This furnace is generally employed for the best kind of work, and will melt many charges in a day, according to the nature of the metal exposed in it.

Plate IV figs. 1. and 2. are two views of forge-hammer machinery, erected by the celebrated Smeaton. *A* is the water-wheel; *H*, a fly-wheel; *D*, wheel-work to open the shuttle by a little at once, for the purpose of adjusting the quantity of water; *F*, a cog-wheel to give motion to the wheel *G*; at the other end, *I*, a number of cogs, which lift the hammer *K*, *fig. 2.* by passing under its shaft, or helve, as it is sometimes termed; *L*, a large beam of wood inserted into the post *M*, and passing horizontally over the hammer. Into the posts, *M* and *N*, is inserted a piece of ash-timber *o*, against which the hammer *K* strikes in its ascent, and by its elasticity re-acts upon the hammer, and

gives it a greater descending velocity than would be produced by gravity alone. *Q* is a number of heavy pieces of metal laid upon the beam *L*, to increase its *vis inertia*, and will, in consequence, receive less motion from the hammer. (See *MILL-WORK* and *WATER-WHEEL.*) The hammer here described has been much improved, so far as regards the spring at *o*.

That already mentioned in the plate is much preferred. The whole of it is made of cast-iron, and its weight is about 35 *cwt.* It acts simply by its gravity; its extra force, therefore, over the common one, consists in its greater quantity of matter. It is made exceedingly massive near the centre of motion, by which means its centre of oscillation is thrown nearer to that point, and it consequently descends with greater velocity. Although this is an advantage with respect to the number of strokes in a given time, it is a disadvantage in another way; since the centre of oscillation is also the centre of percussion, or the point where the greatest stroke is made. Could the velocity be obtained without this evil, the advantage would be material. See *TILTING-MILL.*

IRON, in the *Materia Medica*, is said to have greater virtues than any of the other metals, which is not to be wondered at, as being the only one that is in a manner soluble in the human body. All the other metals, whether hard or soft, poisonous or salutary, nay even fluid mercury itself, swallowed in their crude state, pass out of the body again unaltered; but this is not the case with iron, its crude filings are often taken as a medicine, and are always so much acted upon by their juices, as to produce considerable effects. It is so easily wrought upon out of the body also by fire, and by different menstrua, that it becomes an aperient or astringent, as it is differently treated; and is, under proper management, greatly superior to all other medicines in chronic cases.

Iron or steel, that is, the *ferrum* or *chalybs*, may be employed indifferently, as Cullen suggests, in the preparation of the rubigo; but he thinks that, upon the whole, the preference is due to the iron in its soft malleable state, or in that which is called "forged iron." As iron, says this medical writer, like all other metals, in its solid and entire state, is not active with regard to our bodies, without being corroded or dissolved by saline matters, he is of opinion, that it is rendered active only by being combined with acids. It has indeed been common to give the entire metal, brought by filing into a fine powder, and with very good effects, as a medicine. But this he does not consider as an exception to his general rule; because he is persuaded that there is constantly present in the human stomach a quantity of acid capable of dissolving iron; and as a proof of it he alleges that he never knew iron given in its metallic or slightly corroded state, without producing a blackness in the stools, which affords a presumption of a previous solution of the iron in acids. As this combination with acids is necessary, physicians and chemists have diversified this combination in a variety of ways; Dr. Cullen observes, that he has not known a preparation of iron for the purpose of medicine, that has not been prepared by a combination with acids, or by bringing the iron into a state that rendered it readily soluble by the acid of the stomach, and Dr. Lewis very properly remarks, that Prussian blue, though truly containing a quantity of iron, as it is not soluble in any acid, is the least promising of all the medicinal preparations.

Its virtues internally were not unknown to the ancients; Dioscorides attributes both an astringency and aperientcy to it, and prescribes it in hæmorrhages. He also recommends its rust, or *crocus martis*, in suppressions of the menses;

though he, on the other hand, prescribes wine or water, in which red-hot iron has been quenched, as an astringent in dysenteries, diarrhoeas, and weaknesses of the stomach.

Iron combined with acids becomes an astringent substance; and hence its great medicinal virtue is caused by its tonic and strengthening qualities; for by increasing the tone of the vessels, it increases their vigour and activity. It produces a slight and gentle irritation of the fibres, the effect of which is to constrict the sensible organic parts upon which it acts, and to increase their force and elasticity. Iron particularly acts upon the fibres, and the vessels of the stomach and intestines; hence it produces excellent effects in all diseases which proceed from laxity and inactivity of the digestive organs. Such are crudities, bad digestion, accompanied with diarrhoea, flatulencies, flatulent colics, &c. &c. in diseases which proceed from the former, as many hysterical, hypochondriacal, melancholic affections, intermittent fevers, tertians and quartans, &c. In those cases iron quickens the circulation and raises the pulse; renders the blood more florid, and as it were expands and relieves the juices, promoting, when they are deficient, and restraining, when immoderate, the secretions that are made from the blood, as perspiration, urine, and the uterine purgations. By the same corroborating power, which renders it serviceable in promoting deficient, and restraining redundant discharges, where the suppression or flux arises from debility and relaxation, it increases, on the contrary, fluxes, and confirms obstructions, when they proceed from tension, rigidity, or spasmodic strictures of the vessels. Where either the circulation is quick, or the habit plethoric, by increasing the velocity of the blood, and the plethoric symptoms, it produces heaviness, dulness, vague heats and flushings, or kindles more dangerous fevers or inflammations, or bursts some of the over-distended small vessels. In some constitutions, where iron is proper and salutary, particularly in hysterical and hypochondriacal cases, and where the stomach is very weak, it is apt at first to occasion great sickness and perturbation: to remedy these inconveniences, Sydenham advises, to begin with very small doses, and to administer it for a while at bed-time, in conjunction with a slight opiate. In other circumstances, it is commonly taken in the morning and afternoon, and moderate exercise used to promote its action. In all cases the dose should be small and repeated; a grain, or half a grain of the metal dissolved, or in a soluble state, is generally a sufficient dose. Its effects are known by noxious eructations, and by the alvine feces being tinged of a black colour.

Stahl, and several other modern chemists and physicians, acknowledge only the tonic and strengthening qualities of iron. The cases in which iron has produced a resolving and aperient effect are those, in which the obstructions, and the defect of secretions and excretions, have proceeded from weakness and relaxation of the fibres and of the vessels, rather than from a crassitude of humours, as in the chlorosis, in some kinds of jaundice, and other diseases of the same sort.

The same preparation, as Dr. Lewis has judiciously observed, may sometimes exert an aperient, and sometimes an astringent, power, according to the state of the body to which they are applied. *E.g.* If a retention of menses depends upon a weakness in the vessels of the uterus, chalybeate medicines, by invigorating the force of the vessels, may cure the disease, and may thereby appear to be aperient; and, on the contrary, in a menorrhagia, when the disease depends upon a laxity of the extreme vessels of the uterus, iron exhibited, by restoring the tone of these vessels, may

shew an astringent operation. However, it is probable, that in the cases of suppression depending upon a constriction of the extremities of the vessels of the uterus, the same tonic powers may not be so properly employed. By considerations of this kind, the inutility or propriety of the medicinal preparations of iron may be determined. In all cases of active hemorrhagy they must be hurtful; and in cases of hemorrhagy from external violence, Dr. Cullen would judge them to be useless, if not hurtful. In cases of a general flaccidity, as it is frequently marked under the title of "Cachexy," and in all cases of evacuations from laxity, whether sanguine or serous, they are likely to be the most effectual remedies. The good effects of the preparations of iron, as Dr. Cullen apprehends, have been often missed by their being given in too small doses. The saline preparations, in large doses, are ready to irritate the stomach; and for this reason, and some others, it must be always proper to begin with small doses, and to increase them by degrees; but he has often found, that no great benefit is to be obtained but when large quantities, either by the size of the doses, or by the long continuance of them, have been thrown in. He says, that he has found the simple rust as effectual as any other preparation, and the stomach has borne it better than any other. He begins with a dose of five grains, but gradually increases it to what the stomach easily bears. Some are said to have given it to the quantity of six drams in one day; but he has hardly found any stomach that would bear the third part of that quantity without much sickness. He thinks that the stomach bears it better by joining with it some aromatic.

The preparations of iron that have been in more frequent use, and some of which are at present continued under different names, are, 1. The crude filings reduced to an impalpable powder; this is an excellent form for administering iron in female disorders, in which the body is weak, languid, and full of acidities; the dose of the filings is from two or three grains to a scruple or more. 2. "Mars saccharatus," which is the filings candied with sugar, by dissolving two parts of fine sugar in water, and boiling it down to a candy consistence, and adding, by little and little, one part of the cleansed filings in a kettle over a gentle fire; the vessel being continually shaken, that the filings may be cruised over with the sugar. In order to prevent the mixture from running into lumps, a little starch is previously mixed with the sugar, in the proportion of a dram to a pound. 3. "Lima-tura Martis preparata," or "Chalybis rubigo preparata," is formed by moistening the filings with vinegar or water, and exposing them to a moist air, or occasionally moistening them afresh, which soon change in great part into rust; this rust may be separated from the uncorroded part, by grinding and washing over the fine powder with water. This is given in the same dose as the crude filings.

This preparation, which was denominated "chalybis rubigo preparata" in the London Pharmacopeia of 1745, and "ferri rubigo" in that of 1787, is now called "ferri carbonas," or carbonate of iron. It is formed of sulphate of iron, eight ounces; sub-carbonate of soda, ten ounces; and a gallon of boiling water. Dissolve the sulphate of iron and sub-carbonate of soda separately, each in four pints of water; then mix the solutions together, and set by the mixture, that the precipitated powder may subside; having poured off the supernatant liquor, wash the carbonate of iron with hot water, and dry it upon bibulous paper in a gentle heat.

There are two oxyds of iron, both of which are combined with acids, and form different modifications of the same salt, a distinction that ought to be particularly regarded

in medicine; they have been named, from their colour, black and red oxyds; the former, which is black, or (if formed as in the present instance, by precipitation from water) greenish, consists of iron 73, and oxygen 27, according to Lavoisier. It may be formed in various ways: as by exposure of a paste of iron-filings and water to the air; by heating together one part of red oxyd of iron, and two parts of iron-filings; and by adding a solution of alkali to one of green sulphate of iron, and drying the precipitate quickly without exposure to air; and it is kept as a separate article in the Edinburgh Pharmacopeia, under the name of "*Ferri oxydum nigrum purificatum*." The latter, or red oxyd, consists, according to Proust, of iron 52, oxygen 48, and in its relation to black oxyd is composed of 66.5 of that oxyd, and 33.5 of additional oxygen. Some chemists have supposed the existence of other gradations of combination of iron and oxygen, but the above are all that are generally admitted, or that require particular notice; this latter is also kept in the Edinb. Pharmac. under the name of "*oxydum ferri rubrum*." Salts containing the black oxyd, on exposure to air, pass to the state of red oxyd, by attracting oxygen from it, and in the process of drying, the same change happens here to the oxyd in the sub-carbonate, which, at the time of its first precipitation, is a black oxyd. The same substance, more imperfectly prepared, constituted the rust of iron (*ferri rubigo*) of the former Pharmacopeia, for which, in all the processes into which it entered, this precipitate is now substituted. The red oxyd of the Edinburgh college is the old "*Colcothar vitrioli*," and formed by exposure of common sulphate of iron to a strong heat, sufficient to drive over its sulphuric acid, when the red oxyd remains behind, as in the process which was formerly in use for obtaining that acid. Sub-carbonate of soda is preferred for the precipitation to that of potash, on account of the greater solubility of the sulphate of the former than of the latter alkali, and the consequent facility with which it may be washed away. The salt is a sub-carbonate, but as only one of the compounds is kept, the relation is not expressed. The dose of the "*ferri carbonas*" is from two to ten grains.

4 "*Mars sulphuratus*," prepared by mixing iron-filings with twice their weight of flower of brimstone, and as much water as will make them into a paste, which in a few hours swell up, and is then pulverized, and put into a heated crucible to deslagrate, and kept constantly stirring with an iron spatula, till it falls into a deep black powder: this powder urged longer in the fire, becomes red, and is called, 5. "*Crocus martis aperiens et astringens*." 6. The salt or vitriol of iron, "*ferrum vitriolatum*," called "*Sal martis*." This is now disused. See *Crocus Martis*.

This is the "*ferri sulphas*," sulphate of iron, of the Lond. Pharm. of 1809; and is composed of iron and sulphuric acid, of each by weight eight ounces, and four pints of water. The sulphuric acid and water are mixed together in a glass vessel, and the iron is added; then, after the effervescence has ceased, the solution is filtered through paper, and evaporated, so that crystals may form as it cools. The water is afterwards poured away, and the crystals are dried upon bibulous paper. Upon a large scale this salt is formed from native sulphuret of iron (*pyrites*) by moistening, and exposing it to the open air. The sulphate of iron is afterwards dissolved in water and crystallized by evaporation. Sulphuric acid will unite either with the black or red oxyd: the first of these is the salt here intended for internal use, and upon this point great stress ought to be laid; as the last is the state in which the sulphate of trade is usually found, and which, for medical purposes, is a very distinct and inferior

thing. Its crystals are transparent rhomboidal prisms, of a light green colour; its taste is astringent and strong, and it reddens vegetable blues. One part is soluble in two of cold, and in three-fourths of boiling water. It is insoluble in alcohol, in which menstruum the red sulphate is soluble, and this affords a method of ascertaining the existence of the latter with the former, as also of separating it. On exposure to air it is gradually converted into red sulphate: it consists, according to Kirwan, of acid 26, iron 28, and water 46, parts. Heat drives off the water of crystallization, and the salt remains white: if urged farther, it drives over the acid, and leaves first a red sulphate, and at last a red oxyd of iron. The dose of the "*ferri sulphas*" is from one to five grains. 7. "*Tinctura martis in spiritu salis*," P. L. 1745, "*Tinctura ferri muriate*," P. L. 1787, or "*Tinctura ferri muriati*," tincture of muriate of iron, P. L. 1809. This is formed by pouring the muriatic acid, in the proportion of a pint, upon half a pound of carbonate of iron in a glass vessel, and shaking it occasionally for three days: then setting it by, that the forces, if there be any, may subside; pouring off the solution, and adding three pints of rectified spirit. This salt appears to be an oxymuriate of iron, the red oxyd of iron employed becoming, on its combination with the acid, black oxyd, and giving over its superabundant oxygen to the muriatic acid. This appears to be its state, because sulphuric acid added to it detaches oxymuriatic acid, and heat drives over oxymuriatic acid; and in the latter instance, although the red oxyd was used for its preparation, the black oxyd remains behind. The salt, evaporated to dryness, yields an orange-coloured mass, which is uncrystallizable, deliquesces on exposure to air, and is soluble in alcohol. The tincture has a brownish yellow colour, and very astringent taste. 8. "*Flores martiales*," P. L. 1745, flowers of iron (see *Flores*), "*Ens Veneris*," P. L. 1720, "*ferrum ammoniacale*," P. L. 1787, or "*ferrum ammoniatum*," ammoniated iron, P. L. 1809, is composed by intimately mixing carbonate of iron and muriate of ammonia, of each a pound, and subliming by immediate exposure to a strong fire, and, lastly, reducing the sublimed ammoniacal iron to powder. This substance consists of red muriate of iron, mixed by sublimation with muriate of ammonia. It is orange-coloured, with a smell resembling saffron, is deliquescent, and soluble in alcohol. The residue, which is deliquescent, consists also of red muriate of iron, and was formerly kept under the name of "*lixivium martis*." The dose is from three to fifteen grains. 9. "*Tinctura florum martialium*," P. L. 1745, "*Tinctura martis Mynsichti*," P. L. 1720, "*Tinctura ferri ammoniacalis*," P. L. 1787, or "*Tinctura ferri ammoniati*," tincture of ammoniated iron, P. L. 1809, is formed by digesting four ounces of ammoniated iron in a pint of proof spirit, and then straining. This is an elegant chalybeate, and may be given in doses of a teaspoonful. 10. "*Ferrum tartarizatum*," or tartarized iron, P. L. 1787 and 1809, called also "*Mars solubilis*," and "*Chalybis tartarizatus*," consists of iron, a pound, super-tartrate of potash, powdered, two pounds, and a pint of water. Rub them together, and expose them to the air in a broad glass vessel for eight days, then dry the residue in a sand bath, and reduce it to a very fine powder. Add to this powder a pint more of water, and expose it for eight days longer; then dry it, and reduce it to a very fine powder. This is a triple salt, in which the iron is first oxydated by being moistened and exposed to air, and then combines with the superabundant acid of the super-tartrate of potash; and it is therefore a tartrate of potash and iron. It may be dissolved in water and crystallized. This elegant and useful chalybeate may be given either in a solid or liquid form, from five

grains to a scruple. It has been usually distinguished in the shops by the name of its inventor, Dr. Willis. 11. "Liquor ferri alkalini," or solution of alkaline iron, is composed of $2\frac{1}{2}$ drams of iron, two fluid-ounces of nitric acid, six fluid-ounces of distilled water, and six fluid-ounces of the solution of subcarbonate of potash. Having mixed the acid and water, pour them upon the iron, and when the effervescence has ceased, pour off the clear acid solution; add this gradually, and at intervals, to the solution of subcarbonate of potash, occasionally shaking it, until it has assumed a deep brown red colour, and no farther effervescence takes place. Lastly, set it by for six hours, and pour off the clear solution. This preparation was first described by Stahl, and called "tinctura martis alkalina," and it is for the first time introduced into the London Pharmacopeia of 1809, as affording a combination of iron distinct from any other, and often applicable to practice. It seems to be a triple salt, formed by the union of nitric acid with red oxyd of iron, and with potash. Dr. Lewis has observed, that alkaline solutions of iron are ill adapted for medicinal use; and on that account, he says, they have been wholly neglected in modern practice. 12. "Vinum chalybeatum," P. L. 1745, consists of two ounces of iron-filings mixed in two pints of wine. The mixture is set by for a month, occasionally shaking it, and it is then filtered through paper. Lewis Mat. Med. Cullen Mat. Med. London Pharmac. 1809. See *Chemical Properties of IRON, Chalybeates, and Mineral, &c. WATERS.*

IRON, Case-hardening of, a process by which a superficial hardness is given to various articles made of iron. It is found by experience that pure iron is not susceptible of a very fine polish, and that, when it is exposed to the air, it very soon changes. All iron utensils, therefore, such as fire irons, and many other articles, having the appearance of polished steel, are case-hardened, for the purpose of giving them a finer polish, as well as rendering their colour more permanent. The goods to be case-hardened should be finished with the exception of polishing, since, if the process be well managed, the most delicate workmanship will not be injured. A box of wrought iron must be provided, which is perfectly found in every part, having a lid of the same metal, to fit very tight. In this box the articles are to be stratified with powdered carbon, that of animal substances being the best, for reasons given in the article IRON, in the section on *Steel*. The box being perfectly filled with these materials, let the lid be fitted on, and luted all round with a paste made of equal parts of pipe-clay and Calais sand. The whole is now to be surrounded by bricks loosely built up, a little higher than the top of the box, leaving about four inches on each side for fuel. This may be done either upon a smith's hearth or in the open air. The most proper fuel is the refuse-cokes from any fires where pit-coal is burnt. The fire being kindled, and the space filled up with this fuel, the heat will be applied gradually, owing to the smothered combustion. As soon as the box appears of a light red heat, let it remain about half an hour, or more time if the box be large, in the same temperature. The lid may now be taken off, and the box inverted and its contents emptied over a cistern of cold water. If the box be suffered to cool without being opened, the goods will be perfectly white and metallic when taken out. If they are now heated red-hot, and quenched in cold water, they acquire the same hardness as if turned out of the box red-hot into the water. If the articles are very delicate, so as to be injured by the air in heating a second time, they may be preserved, by dipping them into a mixture of a saturated solution of salt (muriate of soda) with any vegetable matter to give it a pulpy consistence. During the time of

heating it red-hot, the salt fuses upon the surface of the metal, defending it from the oxygen, so that after it is quenched in the water, and brushed, it will be perfectly clean.

The size of the iron box should not be very large; it is better to do the work at two or three processes. Charcoal is a very bad conductor of heat, and if the mass to be heated were large, those articles near the sides would be over done, by combining with too much carbon, while those in the middle would be too little carbonated.

People in the habit of case-hardening, have generally some secret receipt for the process, on which they set great value. All, however, agree in using carbon, the only thing necessary: some add to this salt-petre; others sal ammoniac, and other articles, to which they very knowingly attribute their relative success. We can, however, assure the most sage of these persons, that if they make their box perfectly air-tight, by the rules above given, stratifying the articles with animal carbon alone, they will, with proper heat and time, produce the greatest possible effect.

Animal carbon may be produced from most animal substances: among these are blood, hoofs, and leather. These substances should be pressed into an iron pot, which can be heated red-hot, covered close, with a small open tube inserted into the cover. The volatile matter that escapes may be set on fire, which will in a great measure destroy the smell; or a receiver may be adapted, and the crude ammonia distilled off. When the volatile substances have come over, the residuum will be fine animal carbon, which requires only to be reduced to powder.

This animal carbon is so fitted for combining with iron, that if it be made into a pulp with a saturated solution of salt, and laid upon the surface of iron; upon being heated red-hot, and quenched in cold water with this coating upon it, the surface will become hard. Any part of an iron article, not wished to be case-hardened, may be prevented from undergoing the change, by covering the part with pipe-clay.

IRON, For the bluing of, see BLUEING.

IRON, For the expansion of, by heat, see HEAT and PYROMETER.

IRON Chambers. See CHAMBERS.

IRON, For the refining of. See REFINING and IRON, § 4. *supra*.

IRON, For the conversion of, into steel. See IRON and STEEL.

IRON Furnace. See BLAST-Furnace, and IRON, *supra*.

IRON, Harping. See HARPING.

IRON-liquor, in *Calico Printing and Dyeing*, is a solution of iron in the acetic acid, used as a mordant for certain colours. It is employed as a substitute for the sulphat of iron, and is preferred, in those processes, to the last salt. The oxyd of iron, which is the essential ingredient, is more easily attracted by the stuff from the acetic than the sulphuric acid, and, besides, the texture is not so liable to be injured by the acetat as the sulphat of iron. In order to make this substance cheap, the acid distilled from wood, called pyrolignic acid, and now found to be impure acetic acid, is used as a substitute for vinegar. See PYROLIGNIC Acid, and the last section of the article IRON.

IRON-moulds are marks or stains produced on substances, particularly linen and cotton, by the oxyd of iron. The affinity of these vegetable substances for the oxyd of iron is so great, as not only to take it from the surface of iron, but from any acid with which it may be combined. We find, hence, that very few acids are capable of removing iron-moulds. From the well-known fact that the attraction of acids for oxyds of metals is more feeble as the latter contain

more oxygen, we are enabled to account for iron-moulds being easier to remove, as they are more recent. The stain soon acquires an orange-red colour, by absorbing oxygen, and is with more difficulty extracted. Various means are employed by the laundresses for removing stains of iron, the most general of which is the citric acid, commonly called salt of lemons. The muriatic acid is frequently employed by the bleachers, and it is by far the most rapid and effectual process; but the great caution necessary, in suddenly washing the spot after the stain has disappeared, lessens its utility for domestic use. When the spot is dipped into the clear muriatic acid, the iron almost instantly disappears, and it is at that instant the part should be plunged into a quantity of clean water, and washed as quick as possible; the washing being continued for a considerable time.

In order to render the oxyd of iron more easily soluble by any acid, let the part stained be steeped for some time in a solution of sulphuret of potash, or, what is more easily obtained, sulphuret of lime, rinsing it afterwards in clean water. The oxyd will be deprived of some of its oxygen, and may be removed by almost any acid, when it is so dilute, even, as not to injure the stuff, however long it may remain in it.

It may be proper here to observe, that the tartaric and oxalic acids remove iron-moulds equally well with the citric acid.

When the substance iron-moulded is printed calico, and of a buff colour, or any other colour in which iron is employed as a mordant; it will be found that, in removing the iron-mould, the proper colour will also disappear. In this case there is no effectual remedy.

Most of the iron-moulds are produced in the washing, for want of sufficient caution. In those utensils in which metal is at all necessary, copper or zinc should be employed instead of iron. With care, however, iron vessels may be safely used. When they are not in use, the surface of the iron should, after being made clean and dry, be smeared over with oil or tallow, and rubbed dry at the time they are used.

IRON-moulds, yellow lumps of earth or stone, found in chalk-pits about the Chiltern, in Oxfordshire, and elsewhere, being in reality a kind of pyrites, or indigested iron-ore.

IRON-spot, in *Mineralogy*, is a term applied by Mr. Jameson (*Geognos.* vol. iii. p. 47. 159.) to such rocks and stones as are coloured or clouded by the oxyds of iron. Ferruginous is a more common name for this very common appearance in the strata.

IRON-sick, a *Nautical Term*, signifying the decay of the iron fastenings by its corrosion with the sea water, by which

the continuity of the parts is gnawed away by degrees, whereby the vessel is not only rendered weak, but leaky.

IRON-stone, is that species of iron ore which abounds with a considerable proportion of earth, such as lime, or alumine, and is the ore most common in this country. See **IRON**.

The manner of getting iron-stone is divided into three departments: 1. By *stall-work*: 2. By *bell-pits*: and 3. By *open-work*. The first of these methods is employed when the stone lies at a considerable depth. After sinking a shaft to the lower part of the stratum, the ground is excavated in an horizontal direction, leaving at intervals certain parts standing to support the roof of the excavation. The spaces between these pillars are called *stalls*.

The *bell-pit* is employed when the iron-stone lies at some distance from the surface, and where the ground is not sufficiently firm to admit of stall-work. These pits, when first opened, are narrow, but become wider below, assuming the shape of a bell.

The third method, or the *open-work*, is made use of when the stratum containing the stone is nearly basking, or is very near to the surface. The earth is first removed, laying the stratum containing the ore bare, and the stone is got out as from an open quarry.

The argillaceous iron ores are generally called iron-stones, and abound in many of the coal districts. In Mr. Farley's *Agricultural and Mineral Report on Derbyshire*, vol. 1. p. 217, a list of seventy-five places in and near that county is given, where iron-stone has been dug, or where the rakes of iron-stone, as they are there called, have been worked.

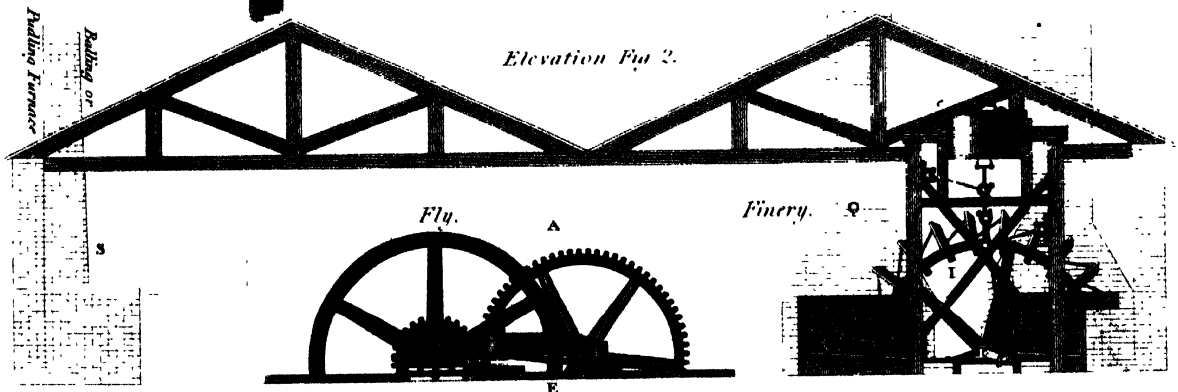
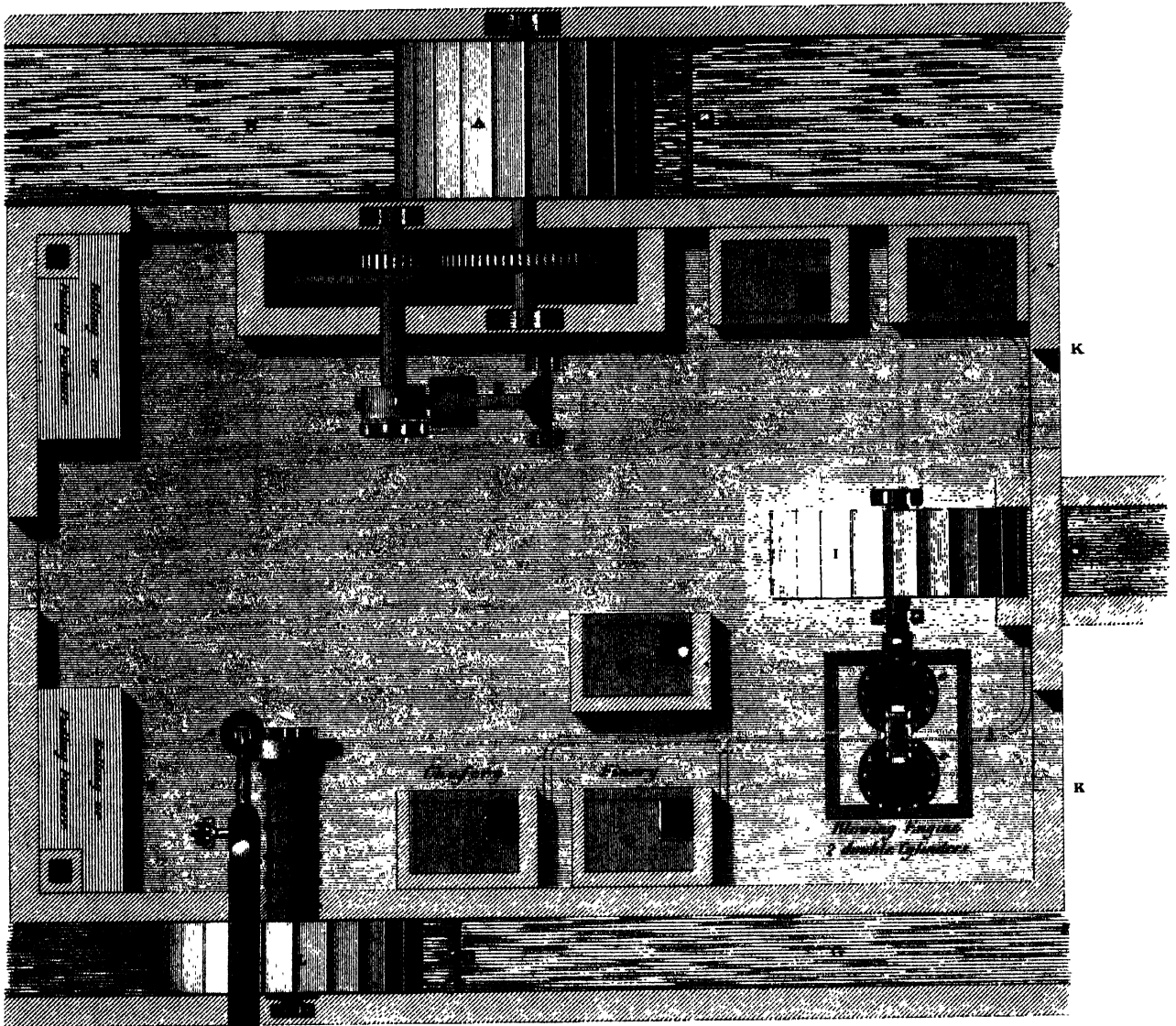
IRON-wood, in *Botany*. See **SIDEROXYLON**.

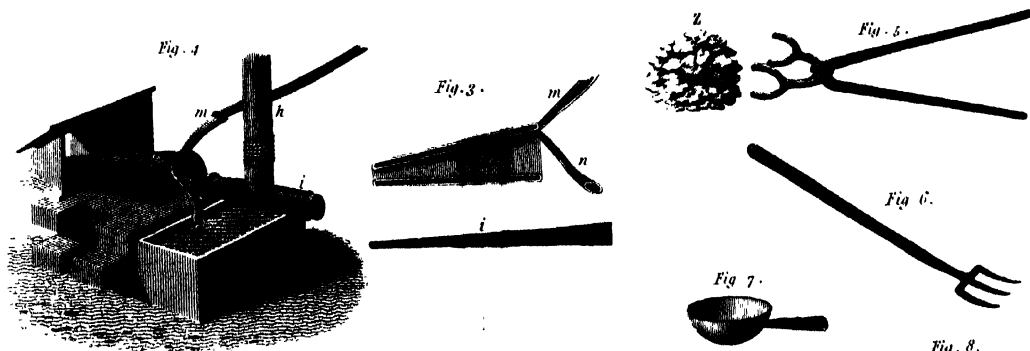
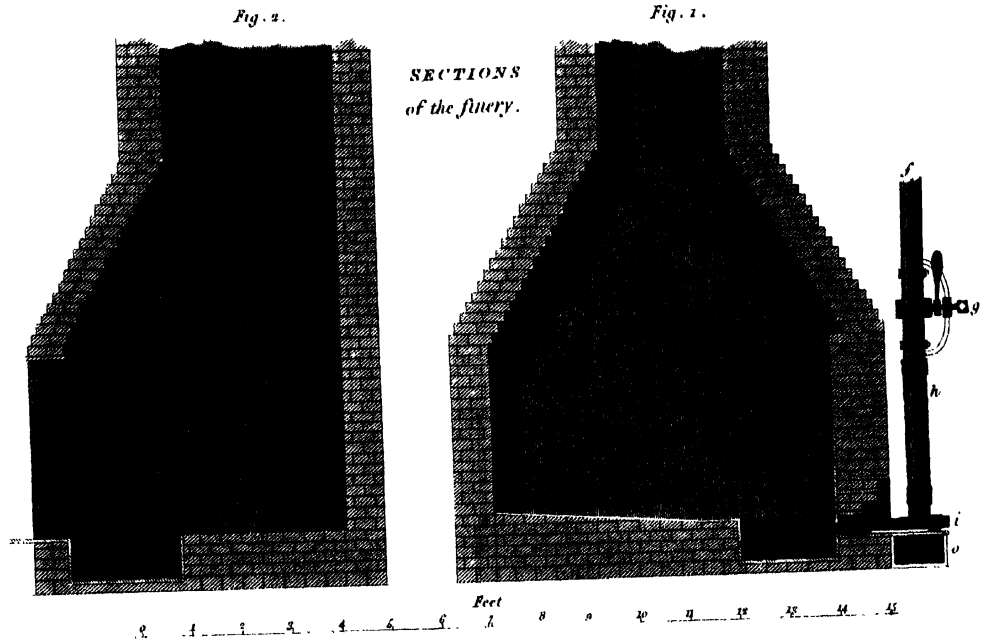
IRON-work, in a *Ship*, denotes all the pieces of iron, of whatsoever figure or size, which are used in its construction; as bolts, boom-irons, which are composed of two rings, nearly resembling the figure of 8, nails, spikes, chains, and chain plates, block-strops, cranks, braces, pintles, and goodgings.

IRON-works, a name given to the establishments for the manufacture of pig-iron. (See **BLAST-furnace** and **IRON**.) The most proper situation for iron-works is on the side of a hill, from which a perpendicular descent could be formed nearly equal to the height of the blast-furnace. The upper ground by this means is on a level with the mouth of the furnace, where all the materials are introduced, and is therefore the situation where the ore is roasted, and the cokes prepared; the lower ground being the most proper for the rest of the works.

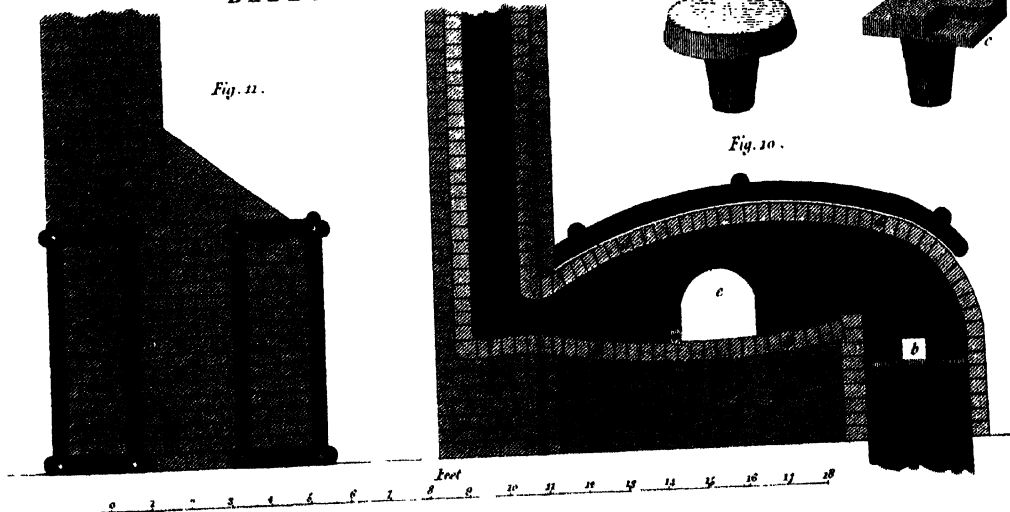
Where such local advantages do not exist, the materials are drawn up on an artificial inclined plane, by appropriate machinery.

Fig. 1. Plan of an Iron Forge.





BALLING FURNACE

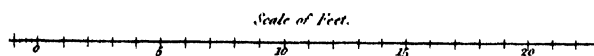
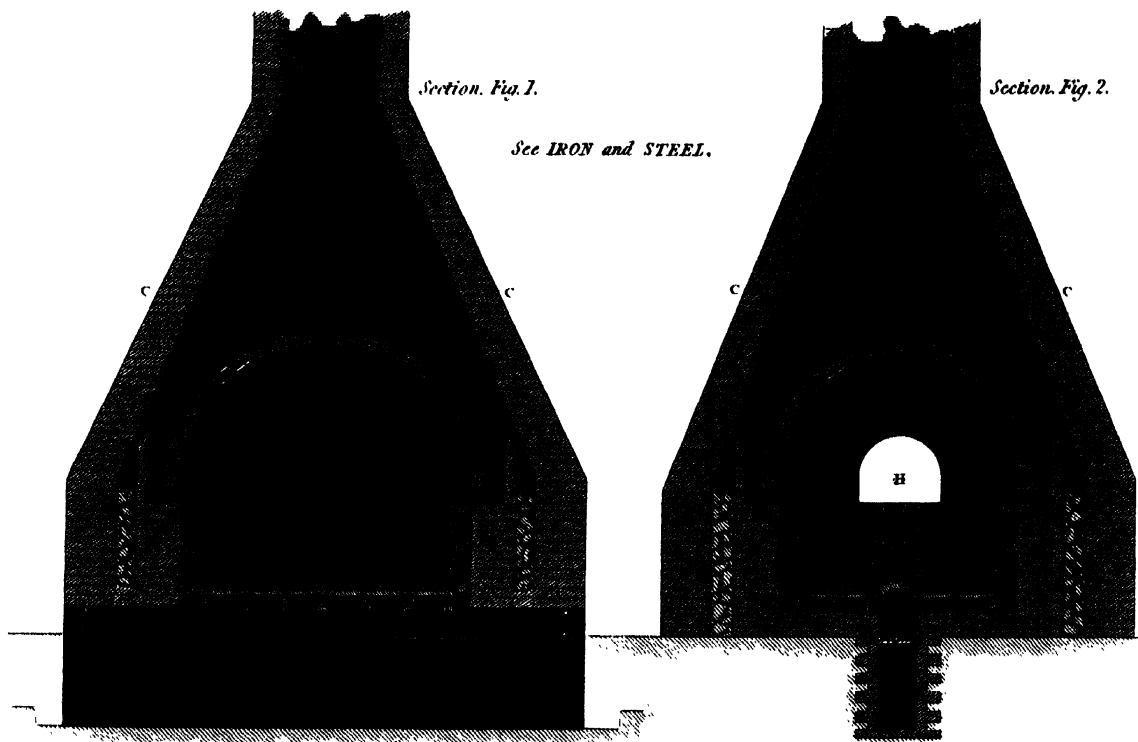


STEEL CONVERTING FURNACE.

Section. Fig. 1.

Section. Fig. 2.

See IRON and STEEL.



Plan.

Fig. 3.

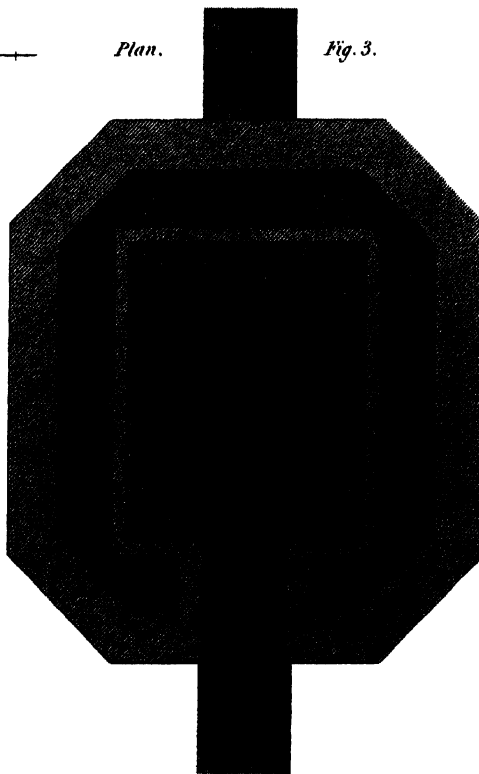


Fig. 4.



Fig. 7.

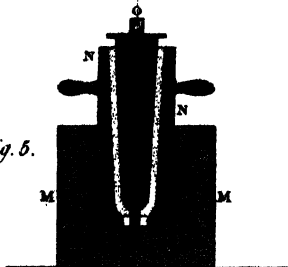


Fig. 6.



Mould for making Crucibles.

Fig. 5.



M^r Smeaton's design for the Machinery of the Hammer at Kilnburst Forge.

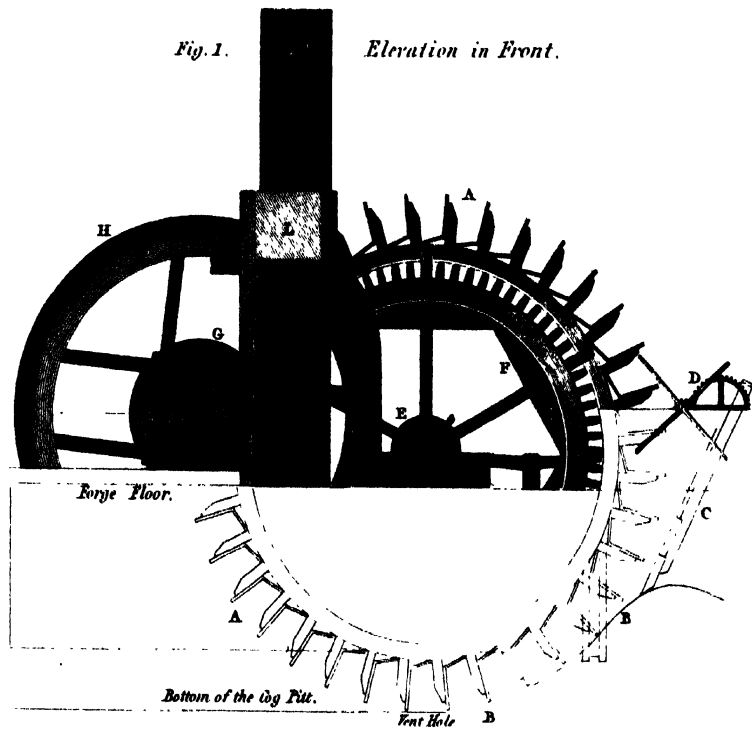
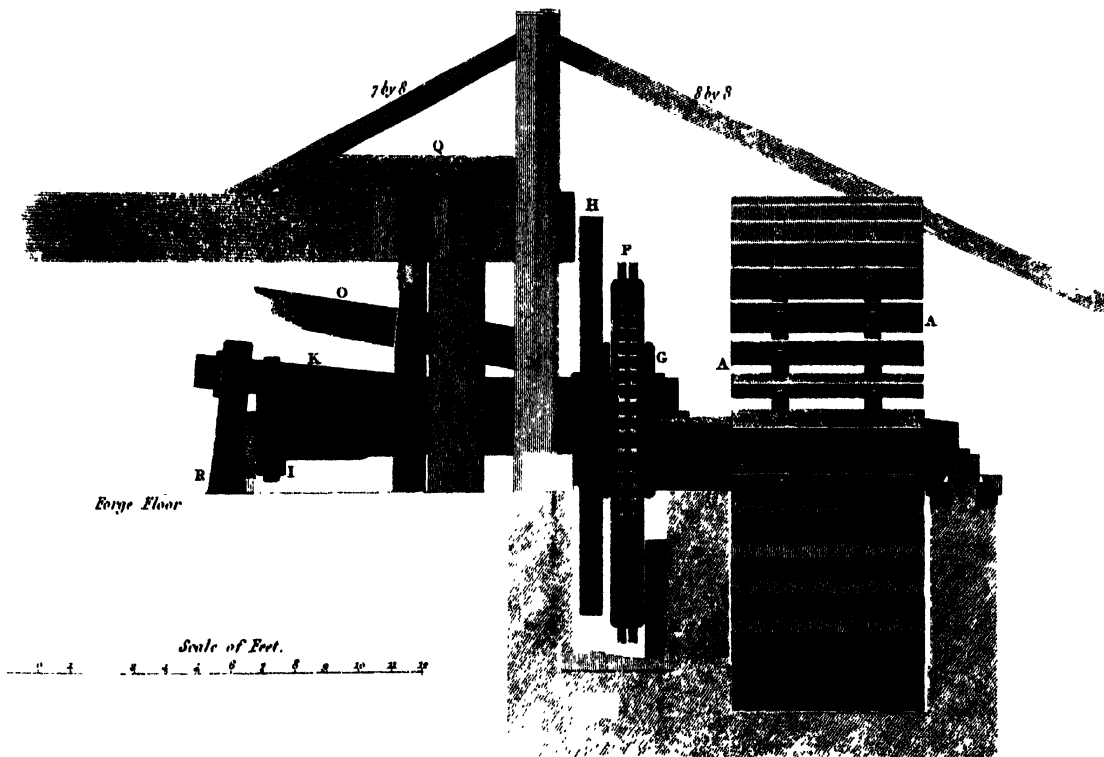
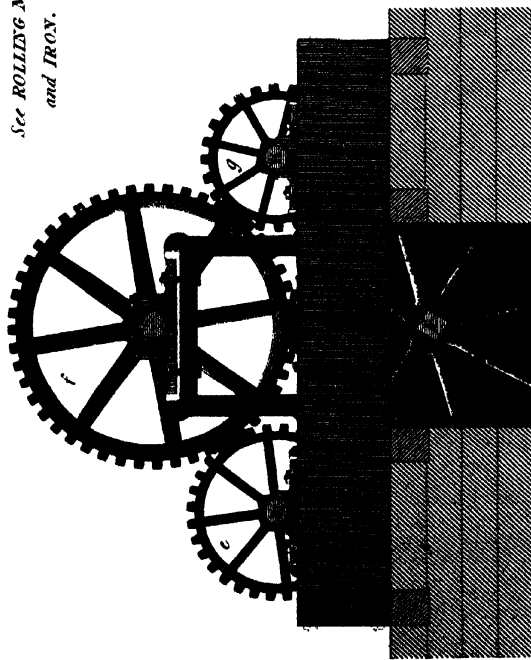


Fig. 2. *Elevation Sideways.*



Elevation. Fig. 2.

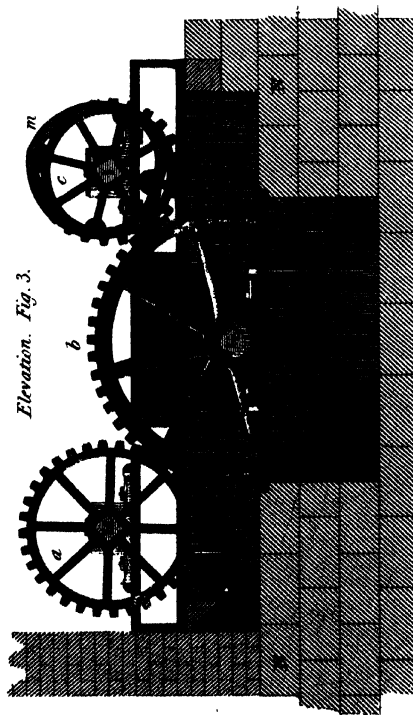


See ROLLING MILL
and IRON.

Scale of Feet.

0 2 3 4 5 6 7 8 9 10 11 12 13 14

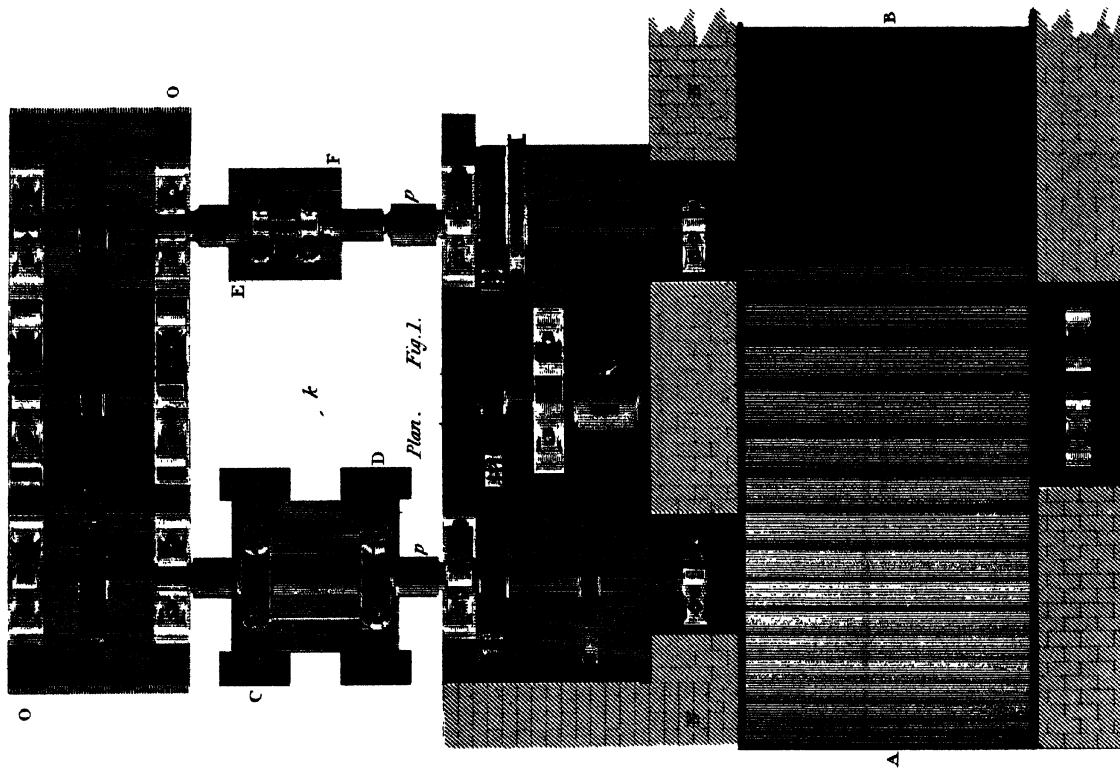
Elevation. Fig. 3.



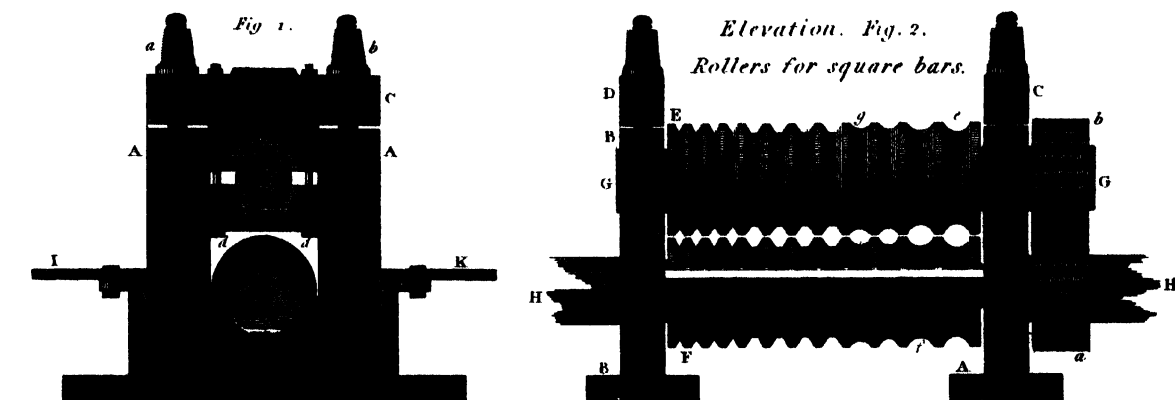
Eng del.

Published as the sole device this by Immanuel Hart 1844 and Henry Patterson New London

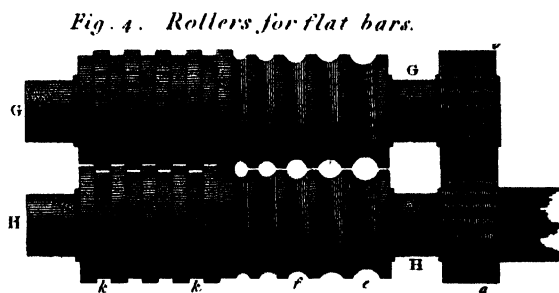
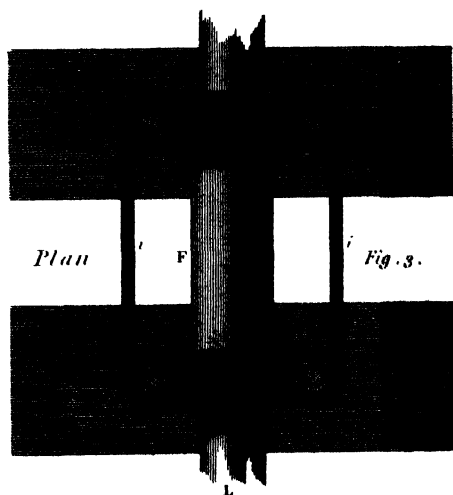
Leary sculp.



ROLLERS for making BAR IRON.

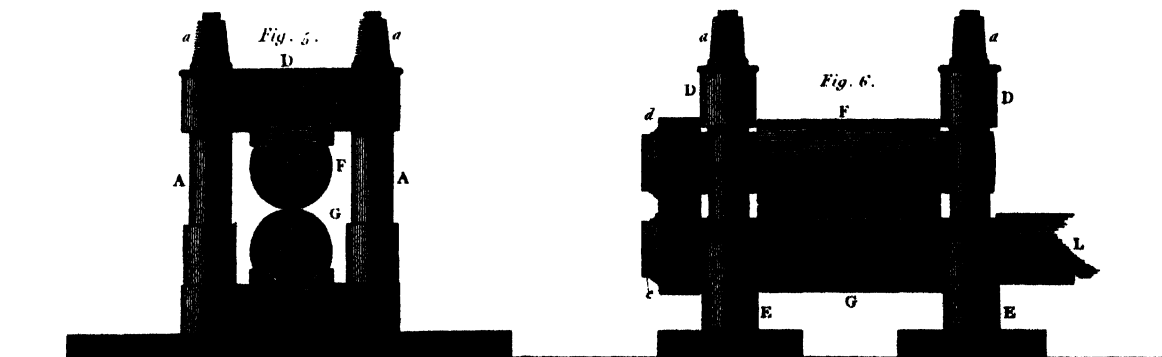


8 9 feet



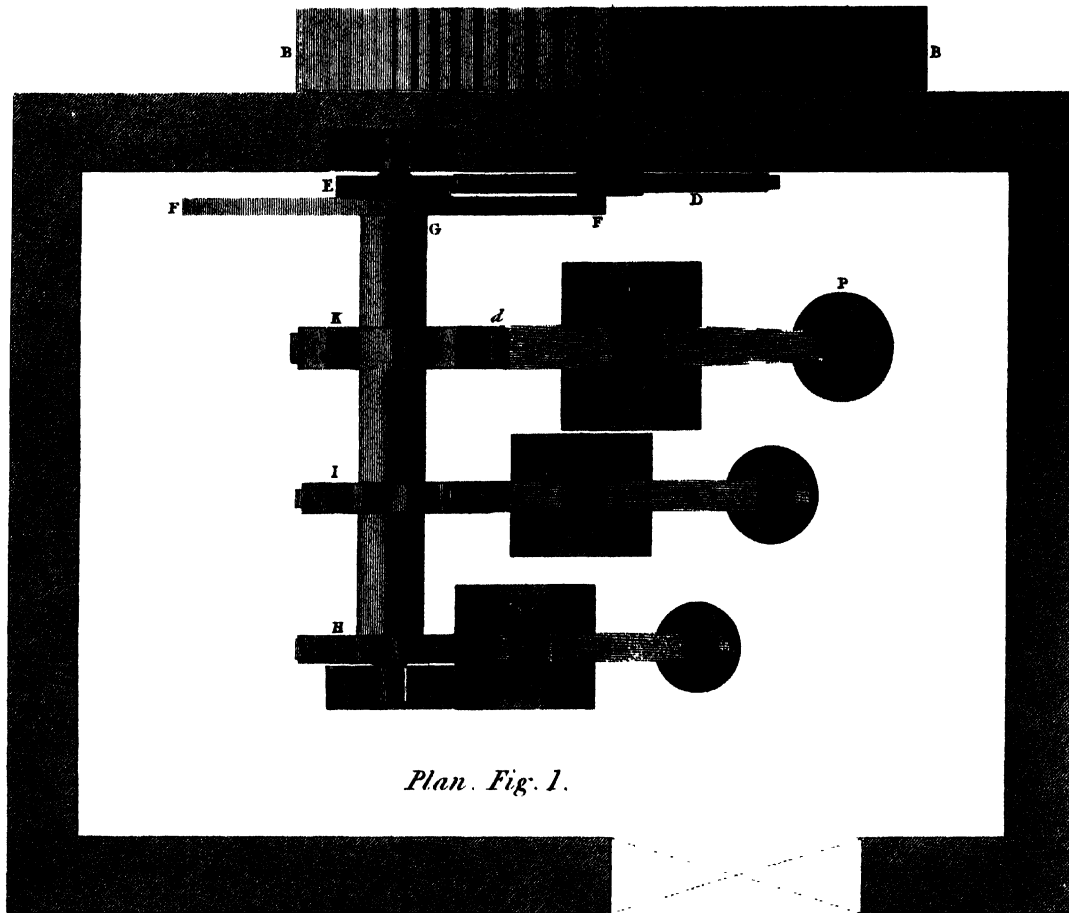
Scale of Feet.

Plate Roller.



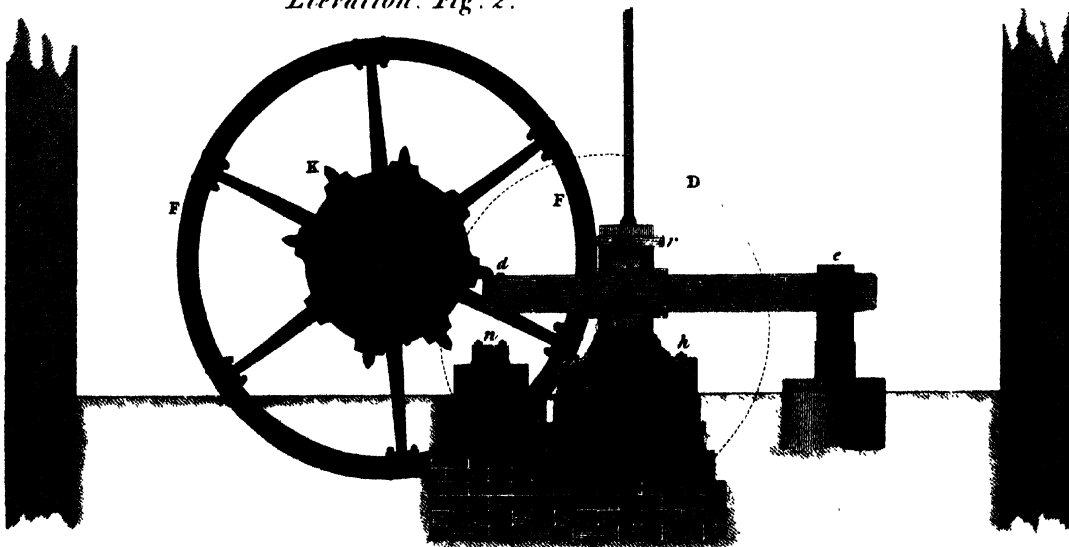
IRON MANUFACTURE
MILL FOR TILTING STEEL,
by M^r. Smeaton.

PLATE VIII.



Plan. Fig. 1.

Elevation. Fig. 2.



Kaolin

KAOLIN, the name of one of the two substances which are the ingredients of china-ware. The other, which is called *petunſe*, is eaſily vitrifiable, and this kaolin is ſcarce at all ſo: whence the fire compoſes from a mixture of them both a ſemi-vitrification, which is china-ware. See **PORCELAIN**.

The kaolin, uſed in the compoſition of porcelain, requires leſs labour than the *petunſe*. There are large mines of it in the boſoms of certain mountains, the exterior ſtrata of which conſiſt of a kind of red earth. Theſe mines are very deep, and the kaolin is found in ſmall lumps, that are formed into bricks, after having undergone the ſame proceſs with the *petunſe*; which ſee. Father d'Entrecolles thinks that the earth called *terre de Malte*, or St. Paul's earth, has much affinity to the kaolin, although it has not thoſe ſmall ſhining particles which are interperſed in the latter.

M. Reaumur had an opportunity of examining this ſubſtance, not in its native ſtate, but only in form of ſmall bricks, made out of the paſte of the powder of the native kaolin and water. He found it of a white colour, and ſprinkled all over with fine glittering particles; but theſe he did not judge to be fragments of a different ſubſtance mixed among the maſs, as are the ſmall flakes of talc in our clays and lands; but that the whole maſs was compoſed of ſome ſtone reduced to powder, and made into a paſte with water, and that theſe larger ſpangles were only coarſer particles of the powder; the examination of which he promiſed himſelf would diſcover what the ſtone was of which they were formed. And this was the more worthy of a diligent inquiry, ſince the *petunſe* might eaſily be ſupplied by many of our own earths and ſands; nothing being required of that but a ſubſtance eaſily running into a white glaſs. But the difficulty of vitrifying this other ingredient renders it a thing much more difficult to be ſupplied by one of the ſame nature among ourſelves. The compariſon of theſe, with other mineral ſubſtances, ſoon proved that they were of the nature of talc; or, in other words, that kaolin was talc powdered, and made up into a paſte with water. And to be aſſured whether the whole maſs was talc powdered, or any thing elſe with a mixture of talc, he ſeparated the particles of the kaolin by water, and found the ſmall ones wholly the ſame with the larger; and that the larger, when reduced to powder alone, made with water a paſte wholly the ſame with the kaolin. It is well known, that the fragments of talc have a great reſemblance to the pearly part of ſome ſhell fiſhes; and hence unqueſtionably has ariſen the opinion of porcelain being made of ſea ſhells; ignorant perſons having ſeen the talc of kaolin, and taken it for a ſhelly matter. Talc has not yet been ſucceſsfully uſed in any of our European manufactures of porcelain; but it is eaſy to

ſee, from many unanſwerable reaſons, that ſince China porcelain is made of a mixture of vitrifiable and unvitriſiable matter, nothing is ſo likely to ſucceed with us in the place of the laſt of theſe as talc.

1. We know no ſubſtance in the ſoſſile world ſo difficult to reduce to glaſs as talc, which, if put into the ſtrongeſt of our fires, in a crucible, is not to be vitrified, nor even calcined. 2. We know no ſubſtance which keeps ſo much brightneſs after having paſſed the fire as talc, or that is of ſo pure a white; whence we may alſo learn that it is not to the *petunſe* alone, that the china-ware owes its whiteness, but that the kaolin is inſtrumental to the giving it that colour. 3. Talc is transparent, nay, and in ſome degree keeps its tranſparence after the action of the moſt violent fire. If we are to make porcelain of a vitrifiable and unvitriſiable matter mixed together, yet it is neceſſary that the unvitriſiable one ſhould retain its tranſparence, otherwiſe it would obſcure the maſs; and talc is therefore the only known ſubſtance qualified for this purpoſe. Perſons who have been at the china works, ſay, that the porcelain is made of equal quantities of *petunſe* and kaolin, and it is therefore a juſt and exact ſemi-vitrification. 4. Talc is well known to have a great flexibility or toughneſs, and as it is found to preſerve this even after it has paſſed the fire; it is very probable, that it is owing to this property of the kaolin that the china-ware is ſo much leſs brittle than glaſs. Mem. Acad. Par. 1727.

It has been before obſerved, that we may eaſily, in Europe, be provided with different ſubſtances, which will, in our porcelain manufactures, ſupply the place of the *petunſe* of China, and talc appears equally qualified to ſerve inſtead of the kaolin. For this purpoſe we may uſe the common Muſcovy talc, or iſinglaſs, uſed by our miniature-painters to cover their pictures inſtead of glaſs, and, by the curious, to preſerve objects for the microſcope; or perhaps the Venetian talc of the druggiſts would ſucceed even better; at leaſt the proceſs is ſo rational, as to be extremely well worth trying.

But this kaolin is more probably an argillaceous earth, from its forming with water a maſs tenacious enough to be made into the loaves into which it is brought over. M. Bomare ſays, that by analyſing ſome Chineſe kaolin, he found it was a compound earth, conſiſting of clay, to which it owed its tenacity; of calcareous earth, which gave it a mealy appearance; of ſparkling particles of mica, and of ſmall gravel or particles of quartz cryſtals. He ſays, that he has found a ſimilar earth upon a ſtratum of granite, and conjectured that it may be decompoſed granite. This conjecture is the more probable, as kaolins are frequently found in the neighbourhood of granites. See **CLAY**, **HOACHE**, and **PORCELAIN Earth**.

Kiln

KILN, in *Agriculture*, a kind of oven or stove for admitting heat, in order to dry substances of various kinds, as corn, malt, hops, &c. It also signifies a fabric or building constructed for the purpose of burning lime-stone, chalk, and other calcareous stones, into lime. Kilns are of different kinds, and formed in different ways, according to the purposes for which they are designed.

KILN-Ashes, the ashes made in kilns where wood, straw, furze, &c. are burnt. These ashes are useful as manure for almost any kind of soil, but especially such as possess much vegetable matter. In the western districts, the farmers sift them over their corn and grafs; but this must not be done in windy weather, because they are so very light, that they would easily be blown away and lost. They are found to succeed best when laid on just before rain falls. See **ASHES**.

KILN, Brick. See **BRICK-Kiln** and **BRICK**.

KILN, Hop, a stove or kiln constructed for the purpose of drying or stoving hops. See **HOP** and **OAST**.

KILN, Lime, a sort of kiln constructed for the purpose of burning various kinds of calcareous substances, such as lime-stone, chalk, shells, &c. into lime. They are built of different forms or shapes, according to the manner in which they are to be wrought, and the kinds of fuel which are to be employed. It has been remarked, in a work on landed property, that, in places where materials are dear, from their being fetched from a distance, and where the fuel is coals, and also expensive, the form of a kiln is mostly that of an inverted cone, a form which has its inconveniencies; but in districts where the art of burning lime is practised with superior attention and correctness, the form has of late years been gradually changing from conical to elliptical. But, in his opinion, "the best form of a lime furnace, in

the established practice of the present day, is that of the egg placed upon its narrower end, having part of its broader end struck off, and its sides somewhat compressed, especially towards the lower extremity; the ground plot or bottom of the kiln being nearly an oval, with an *eye*, or draft-hole, toward each end of it." It is supposed that "two advantages are gained, by this form, over that of the cone. By the upper part of the kiln being contracted, the heat does not fly off so freely as it does out of a spreading cone. On the contrary, it thereby receives a degree of reverberation, which adds to its intensity." But the other, and still more valuable effect is this: "when the cooled lime is drawn out at the bottom of the furnace, the ignited mass, in the upper parts of it, settles down, freely and evenly, into the central parts of the kiln; whereas, in a conical furnace, the regular contraction of its width, in the upper as well as the lower parts of it, prevents the burning materials from settling uniformly, and levelling downward. They "hang" upon the sides of the kiln, and either form a dome at the bottom of the burning mass, with a void space beneath it, thereby endangering the structure, if not the workmen employed; or, breaking down in the centre, form a funnel, down which the under-burnt stones find their way to the draft-holes." And "the contraction of the lower part of the kiln has not the same effect; for, after the fuel is exhausted, the adhesion ceases, the mass loosens, and, as the lime cools, the less room it requires. It therefore runs down freely to the draft-holes, notwithstanding the quick contraction of the bottom of the kiln or furnace."

And, lastly, that, "with respect to the lime-furnace (which is, he thinks, entitled to the most sedulous attention of agricultural chemistry), the fire requires to be furnished

with a regular supply of air. When a kiln is first lighted, the draft-holes afford the required supply. But after the fire becomes stationary, in the middle, or towards the upper part of the kiln (especially of a tall kiln), while the space below is occupied by burnt lime, the supply from ordinary draft-holes becomes insufficient. If the walls of the kiln have been carried up dry or without mortar, the air finds its way through them to the fire. In large deep kilns that are built with air-tight walls, it is common to form air-holes in their sides, especially in front, over the draft-holes. But these convey the air, in partial currents, to one side of the kiln only, whereas that which is admitted at the draft-holes passes regularly upward to the centre, as well as to every side of the burning mass; and, moreover, tends to cool the burnt lime in its passage downward, thereby contributing to the ease and health of the workmen. Hence he is of opinion, that the size of the draft-holes ought to be proportionate to that of the kiln, and the size of the stones taken jointly (air passing more freely among large than among small stones), and that the required supply of air should be wholly admitted at the draft-holes. By a sliding or a shifting valve, the supply might be regulated, and the degree of heat be increased or diminished, at pleasure," according to circumstances.

The most ancient kind of lime-kiln is probably that which is made by excavating the earth in the form of a cone, of such a size as may be necessary; and afterwards building up the sides, or not, according to the circumstances of the case: the materials being then laid in, in alternate layers of fuel and stone, properly broken, until the whole is filled up. The top is then covered with sods, in order that the heat may be prevented from escaping; and the fire lighted at the bottom, and the whole of the contents burnt, in a greater or less space of time, in proportion to the nature of the stone, and the quantity that is contained in the kiln. From the circumstance of the top parts of these kilns, in some districts, being covered over, and the sides sometimes built up with sods, they are termed *sod-kilns*, in order to distinguish them from the other sorts. When the whole of the contents of such kilns are grown cold, they are drawn or taken out from the bottom; and the kiln again filled, if necessary. These kilns are obviously intended for burning only one kiln-full at a time. But as the burning of lime in this way is tedious and uneconomical, other methods and forms of kilns have been had recourse to. Where lime is much wanted, either for agriculture or other purposes, they therefore use perpetual kilns, or what are more generally known by the name of *draw-kilns*. These, as all lime-kilns ought to be, are, the author of *Modern Agriculture* says, situated by the side of a rising bank, or sheltered by an artificial mound of earth. They are generally built either of stone or brick; but the latter, as being better adapted to stand excessive degrees of heat, is considered as preferable. The outside form of such kilns is sometimes cylindrical, but more generally square. The inside should be formed in the shape of a hoghead, or an egg, opened a little at both ends, and set on the smallest; being small in circumference at the bottom, gradually wider towards the middle, and then contracting again towards the top. In kilns constructed in this way, it is observed, fewer coals are necessary, in consequence of the great degree of reverberation which is created, above that which takes place in kilns formed in the shape of a sugar-loaf reversed. Near the bottom, in large kilns, two or more apertures are made: these are small at the inside of the kiln, but are sloped wider, both at the sides and the top, as they extend towards the outside of the building. The

uses of these apertures are for admitting the air necessary for supplying the fire, and also for permitting the labourers to approach with a drag and shovel, to draw out the calcined lime. From the bottom of the kiln within, in some cases, a small building, called a *horfe*, is raised in the form of a wedge, and so constructed as to accelerate the operation of drawing out the burnt lime-stone, by forcing it to fall into the apertures which have been mentioned above. In other kilns of this kind, in place of this building, there is an iron grate near the bottom, which comes close to the inside wall, except at the apertures where the lime is drawn out. When the kiln is to be filled, a parcel of furze or faggots is laid at the bottom; over this a layer of coals; then a layer of lime-stone, which is previously broken into pieces, about the size of a man's fist; and so on alternately, ending with a layer of coals, which is sometimes, though seldom, covered with sods or turf, in order to keep the heat as intense as possible. The fire is then lighted in the apertures; and when the lime-stone towards the bottom is completely calcined, the fuel being considerably exhausted, the lime stone at the top subsides. The labourers then put in an addition of lime-stone and coal at top, and draw out at bottom as much as they find thoroughly burned; and thus go on, till any quantity required be calcined. When lime-stone is burned with coals from $2\frac{1}{2}$ to $3\frac{1}{2}$ bushels, on a medium, 3 bushels of calcined lime-stone are produced for every bushel of coals used in the process.

A lime-kiln of this sort is described in count Rumford's *Essays*, which is in possession of the Dublin Society, as well as the principal objects that ought to be had in view in constructing of the kiln pointed out: the first of which is, "to cause the fuel to burn in such a manner as to consume the smoke, which has here been done by obliging the smoke to descend and pass through the fire, in order that as much heat as possible might be generated. Secondly, to cause the flame and hot vapour, which rise from the fire, to come in contact with the lime-stone by a very large surface, in order to economize the heat, and prevent its going off into the atmosphere; which was done by making the body of the kiln in the form of a hollow truncated cone, and very high in proportion to its diameter; and by filling it quite up to the top with lime-stone, the fire being made to enter near the bottom of the cone.

"Thirdly, to make the process of burning lime perpetual, in order to prevent the waste of heat which unavoidably attends the cooling of the kiln, in emptying and filling it, when, to perform that operation, it is necessary to put out the fire.

"And, fourthly, to contrive matters so, that the lime in which the process of burning is just finished, and which of course is still intensely hot, may, in cooling, be made to give off its heat in such a manner, as to assist in heating the fresh quantity of cold lime-stone with which the kiln is replenished, as often as a portion of lime is taken out of it.

"To effectuate these purposes, the fuel is not mixed with the lime-stone, but is burned in a close fire-place, which opens into one side of the kiln, some distance above the bottom of it. For large lime-kilns on these principles, there may be several fire-places all opening into the same cone, and situated on different sides of it; which fire-places may be constructed and regulated like the fire-places of the furnaces used for burning porcelain.

"At the bottom of the kiln there is a door, which is occasionally opened to take out the lime.

"When, in consequence of a portion of lime being drawn out of the kiln, its contents settle down or subside,

the empty space in the upper part of the kiln, which is occasioned by this subtraction of the burned lime, is immediately filled up with fresh lime-stone.

"As soon as a portion of lime is taken away, the door by which it is removed must be immediately shut, and the joinings well clofed with moist clay, to prevent a draft of cold air through the kiln. A small opening, however, must be left, for reasons which are explained below.

"As the fire enters the kiln at some distance from the bottom of it, and as the flame rises as soon as it comes into this cavity, the lower part of the kiln (that below the level of the bottom of the fire-place) is occupied by lime already burned; and as this lime is intensely hot, when, on a portion of lime from below being removed, it descends into this part of the kiln, and as the air in the kiln, to which it communicates its heat, must arise upwards in consequence of its being heated, and pass off through the top of the kiln, this lime, in cooling, is by this contrivance made to assist in heating the fresh portion of cold lime-stone, with which the kiln is charged. To facilitate this communication of heat from the red-hot lime just burned to the lime-stone above in the upper part of the kiln, a gentle draft of air through the kiln, from the bottom to the top of it, must be established, by leaving an opening in the door below, by which the cold air from without may be suffered to enter the kiln. This opening (which should be furnished with some kind of a register) must be very small, otherwise it will occasion too strong a draft of cold air into the kiln, and do more harm than good; and it will probably be found best to close it entirely, after the lime in the lower part of the kiln has parted with a certain proportion of its heat."

The height of the kiln, which is represented in *Plate (Kiln) Agriculture, fig. 1.* is on a scale of 15 feet: its internal diameter below, two feet; and above, nine inches. In order more effectually to confine the heat, its walls, which are of brick, and very thin, are double, and the cavity between them is filled with dry wood-ashes. To give greater strength to the fabric, these two walls are connected in different places by horizontal layers of brick, which unite them firmly: *a* is the opening by which the fuel is put into the fire-place: through this opening the air descends which feeds the fire. The fire-place is represented nearly full of coals, and the flame passing off laterally into the cavity of the kiln, by an opening made for that purpose at the bottom of the fire-place. The opening above, by which the fuel is introduced into the fire-place, is covered by a plate of iron, moveable on hinges; which plate, by being lifted up more or less by means of a chain, serves as a register for regulating the fire. A section of this plate, and of the chain by which it is supported, are shewn in the figure: *b* is an opening in the front wall of the fire-place, which serves occasionally for cleansing out the fire-place, and the opening by which the flame passes from the fire-place into the kiln. This opening, which must never be quite closed, serves likewise for admitting a small quantity of air to pass horizontally into the fire-place. A small proportion of air, admitted in this manner, has been found to be useful and even necessary in fire-places, in which, in order to consume the smoke, the flame is made to descend. Several small holes for this purpose, fitted with conical stoppers, may be made in different parts of the front wall of the fire-place.

The bottom of the fire-place is a grate constructed of bricks placed edgewise, and under this grate there is an ash-pit; but as no air must be permitted to pass up through this grate into the fire-place, the ash-pit door, *c*, is kept constantly closed, being only opened occasionally to remove the ashes: *d* is the opening by which the lime is taken out

of the kiln; which opening must be kept well closed, in order to prevent a draught of cold air through the kiln. As only as much lime must be removed at once as is contained in that part of the kiln which lies below the level of the bottom of the fire-place, to be able to ascertain when the proper quantity is taken away, the lime, as it comes out of the kiln, may be directed into a pit sunk into the ground in front of the opening by which the lime is removed; this pit being made of a proper size to serve as a measure for it. And while the lime is removing from the bottom of the kiln, fresh lime-stone should be put into it above; and during this operation, the fire may be damped by closing the top of the fire-place with its iron-plate. Should it be found necessary, the fire, and the distribution of the heat may, in burning the lime, be further regulated by closing more or less the opening at the top of the lime-kiln with a flat piece of fire-stone, or a plate of cast-iron. The double walls of the kiln, and the void space between them, as also the horizontal layers of bricks by which they are united, are clearly and distinctly expressed in the figure in the plates.

This method of constructing lime-kilns, though ingenious and philosophical, is probably much too expensive for general use.

It is a common practice to burn lime-stone with furze in some places. The kilns which are made use of in these cases are commonly known by the denomination of *flame-kilns*, and are built of brick; the walls from four to five feet thick, when they are not supported by a bank or mound of earth. The inside is nearly square, being twelve feet by thirteen, and eleven or twelve feet high. In the front wall there are three arches, each about one foot ten inches wide, by three feet nine inches in height. When the kiln is to be filled, three arches are formed of the largest pieces of lime-stone, the whole breadth of the kiln, and opposite to the arches in the front wall. When these arches are formed, the lime-stone is thrown promiscuously into the kiln to the height of seven or eight feet, over which are frequently laid fifteen or twenty thousand bricks, which are burned at the same time with the lime-stone. When the filling of the kiln is completed, the three arches in the front wall are filled up with bricks almost to the top, room being left in each sufficient only for putting in the furze, which is done in small quantities, the object being to keep up a constant and regular flame. In the space of thirty-six or forty hours, the whole lime-stone, about one hundred and twenty, or one hundred and thirty quarters, together with the fifteen or twenty thousand bricks, are thoroughly calcined. Kilns constructed in this way may be seen near Wellingborough, in Northamptonshire, and other places in the northern parts of the kingdom. And in many of the northern counties of Scotland, which are situated at a great distance from coal, it is also a common practice to burn lime-stone with peat; and, considering the rude ill-constructed kilns which are used for the purpose, it is astonishing with what success the operations are performed. In some of these districts, it is stated that lime-stone is sufficiently calcined with peats, laid *stratum super stratum*, in kilns formed of turf; but, owing to the quantity of ashes which fall from the peat, the quality of the lime is considerably injured; and from the open and exposed situation of many of these kilns, the waste of fuel is immense. But the most common method of burning lime-stone with peat, is in kilns constructed somewhat similar to those in the districts where furze is used as the only fuel. There are in general only two arches, or fire-places, and the peats are thrown into the bottom of these arches, the fronts of which are seldom closed up, by which means the wind has

often great influence in retarding the operation, and frequently prevents the complete calcination of the lime-stone. An improvement might, it is supposed, be made on these kilns at a very trifling expence: if an iron grate were laid across the bottom of the arch, with a place below for the ashes to fall down, and the front of the arch closed up by a door made of cast-metal, one-third of the fuel might be saved, and the operation performed in a shorter time, and with a much greater certainty, than by the method now practised in such kilns.

In the Communications to the Board of Agriculture, Mr. Rawson asserts, that he has produced a considerable saving in the burning of lime, by constructing his kiln in the manner shewn at *fig. 2*. "It is made twenty feet in height; at the bottom a metal plate is placed one foot in height, intended to give air to the fire; over this plate the shovel that draws the lime runs. The sloped sides are six feet in height, the breadth at the top of the slope is eight feet, the sides are carried up perpendicular fourteen feet, so as that every part of the inside, for fourteen feet, to the mouth, is exactly of the same dimensions. On the mouth of the kiln a cap is placed, built of long stones, and expeditiously contracted, about seven or eight feet high. In the building of the cap, on one side of the slope, the mason is over the centre of the kiln, so that any thing dropping down will fall perpendicularly to the eye beneath. He is here to place an iron door of eighteen inches square, and the remainder of the building of the cap is to be carried up, until the hole at the top be contracted to fourteen inches. The kiln is to be fed through the iron door, and when filled, the door close shut. The outside wall must be three feet at the bottom to batter up to two feet at top, and made at such a distance from the inside wall of the kiln, that two feet of yellow clay may be well packed in between the walls, as every kiln built without this precaution will certainly split, and the strength of the fire be thereby exhausted. At eight feet high from the eye of the kiln, two flues should be carried through the front wall, through the packed clay, and to the opposite sides of the kiln, to give power to the fire." It is observed, that with this kiln, he has produced one-third more lime from a given quantity of fuel; and stones of bad quality will be here reduced into powder, and may be put into the kiln without the necessity of being broken so small as is usual. As many situations will not admit of building a kiln twenty feet high, while other situations may allow of its being built thirty or even forty feet (for it cannot be made too high), the diameter of the kiln should be proportioned to the height to which it is carried up.

And it is further stated, as another application of this sort of contrivance, that "for several years he has made use of a small kiln in an outside kitchen, the height nine feet, the diameter three feet and a half. In the side of the kiln next the fire, he had three square boilers placed, one of them large, containing half a barrel, with a cock, which supplied the family with constant boiling water; for the two others, he had tin vessels made to fit the inside with close covers, in which meat and vegetables with water were placed and put into the two smaller boilers, which never had any water, but had close covers. The tin boilers were heated sooner than on the strongest fire, and when the meat, &c. were sufficiently dressed, the whole was taken out of the metal boilers. At one side he had an oven placed for roasting and boiling meat; the bottom was metal of twenty-six inches diameter, and one inch and a half thick, a flue from the fire went underneath. Even with the bottom of the oven, a grating nine inches square was placed, which opened a

communication between the oven and the hot fire of the kiln. The height of the oven was fourteen inches, shut close by a metal door of eighteen inches square, and the top, level with the mouth of the kiln, was covered by another metal plate of half an inch thick, on which was placed a second oven; the heat which escaped through the half-inch plate, though not near the fire, was sufficient to do all small puddings, pies, breakfast-cakes, &c. &c. The meat in the large oven was placed on an iron frame which turned on a pivot and stood on a dripping-pan, and was turned by the cook each half hour. And over the kiln he had a tiled stage for drying corn, and a chimney at one side, with a cawl on the top, which carried off all steam and sulphur: a large granary was attached to the building. It is added, that the lime, if sold, would more than pay for fuel and attendance; and he has frequently had dinner dressed for fifty men, without interfering with his family business in any great degree.

There is another form of lime-kiln, which answers extremely well for general use, represented at *fig. 3*. in the same plate. This is capable of being built without any very considerable expence.

It has been found, by experience, in some of the northern districts, that lime-kilns are rendered much less liable to crack and burst by having the outside walls carried up in a square manner, than on the usual circular plan.

KILN, Malt, a sort of kiln contrived for the purpose of drying malt or any kind of grain upon. In the construction of kilns of this sort many improvements have lately been made. A description of a kiln of this kind by Mr. Pepper, of Newcastle-under-Line, has been given, in which *fig. 4*. is the ground plan, supposed to be twenty feet square, but, if required larger or smaller, by following the same proportion, it may be made to any size or situation. The dark shaded walls rise four feet high, to put the reflector upon over the fire, and also what the side arches stand upon, the brick piers, that carry the spark-stone, and bearers that the tiles lie upon. Letter *a*, the fire-grate, which lies nine inches below the bottom edge of the reflector; *b*, bottom edge of the reflector; *c, c, c, c*, brick pillars nine inches square, that carry the spark-stone; *d, d, d, d, d, d*, brick pillars nine inches square, that carry the bearers for the floor tiles to lie upon; *e*, shews the bottom of the side arches on each side of the kiln; *f*, exhibits the space between the fire-place and the side arches, for the man to go round to clean the kiln; *g*, the wall on each side of the kiln, that the side arches stand upon. *Fig. 5*. is a section of it; *g*, shews the section of the wall which the side arches stand upon; *h*, the door to go to the fire-place; *i*, the reflector of cast iron that covers the fire; *k*, small door in the reflector to feed the fire; *l, l*, the ears of the reflector that the iron pipes are fitted upon, which convey the smoke, &c. from the reflector round the kiln, to the chimney; *m*, what is commonly called the spark-stone; it prevents the kiln from being too hot in the middle, and assists in spreading the heat to the outsides; *n*, bearers of cast-iron or wood, that carry the kiln floor; *o, o*, shew the ends of the ribs that carry the tiles; *p*, the kiln tiles, that the malt lies upon; *q*, the steam-pipe that conveys the steam from the malt; *c, c*, brick pillars nine inches square, that carry the spark-stone; *d, d*, brick pillars nine inches square, that carry the bearers for the floor tiles to lie upon; *e, e*, shew the arches on each side of the kiln; *u u*, denotes the situation of the pipes under the floor. And *fig. 6*. is a plan of the kiln floor, and shews the ribs that the kiln-tiles lie upon; *o, o*, the cast iron or wood ribs that the tiles lie upon; *n, n*, the bearers that carry the ribs; *d, d*, the tops of the brick

pillars that carry the bearers, &c.; *b*, the reflector that covers the fire, which is of cast iron, about an inch thick, hollow, and on a semicircular plan, as shewn in the figures; *r, r*, the iron pipes that convey the smoke and heat from the reflector, round the kiln, to the chimney, which lies about three feet under the kiln floor, and about the same distance from the side walls, which are supported by iron stays from the side arches; *f, f*, the ends of the iron pipes that go into the chimney; *i, i*, registers to regulate the draught and heat of the kiln; and *fig. 7.* is a section of the chimney.

It is noticed that in the plate the pillars, bearers, &c. that belong to the same thing, are marked with the same letters in all the different figures.

Another kiln of the same sort, invented by Mr. Joseph Coppinger, of Harbour View, near Cove, Ireland, is represented *fig. 8.* This is stated to be particularly adapted to the use of farmers, who, in wet seasons, often lose quantities of grain for want of such convenience. The advantages it appears to possess above the kilns now in common use, are many; first, it may be erected for one-tenth of the expence, if the value of the separate buildings be taken in, which are now almost invariably allotted for this purpose; secondly, any kind of fuel may be used without prejudice to the malt or corn to be dried in it: thirdly, the heat (by the construction of the flues) will be more regularly and evenly distributed without any waste, as at present: fourthly, the health of the people attending, will not, as at present, be exposed to certain injury, by always breathing and sleeping in a heated and unwholesome atmosphere, as their beds will be placed in a shed on the outside of the building. This, in his mind, is the most important part of the plan, and highly worthy the attention of every humane and considerate employer in this way: fifthly, this construction of a kiln may be erected on a loft or ground floor. If in the latter situation, sufficient elevation should be given to the fire-place, so as not to impede the draught. These are the principal advantages that occur to the writer. If the experience of others confirm them, he will be highly gratified: *a*, the main walls; *b*, the flues; *c*, the chimnies; in each of which may be placed a metal damper to regulate the heat. It is recommended, in the case of a new building, to carry up the flues of the chimnies in the thickness of the walls. In a house already built, they may be carried up either inside or outside the building: *d*, the fire-place, which may be divided, or in one, just as desired, by which the half or the whole may be heated, as is most convenient.

It is stated that kiln tiles eighteen inches square, and two inches thick in the solid, with a lapping of half an inch broad and one inch deep round the edge of each tile, are proposed for covering the flues, which, if fairly cast, may be laid dry, without mortar. If it should be difficult, or too expensive, to procure tiles of eighteen inches, nine inches can be made to answer. The flues are proposed to be divided by a brick, on edge, so as that every eighteen-inch tile will cover two flues. The breadth of the flues may be six inches and a half, and ten inches high. This proportion, it is hoped, will be found to answer in most cases; but it may be varied according to the better judgment of the party erecting. The sides and bottoms of the flues should be plastered. The platform of this kiln should, in all cases, be well rammed with earth, and made perfectly level before laying out the flues. Iron grate-doors are intended to be hung on hinges, in a recess, at the mouth of each flue, to prevent them being choked with large pieces of cinder, or other substances. It is also intended that these doors should shut and open at pleasure, as may be found necessary in carrying on the business.

KILN Tiles, in Rural Economy, the name of that sort of tiles which are employed in malt and other similar sorts of kilns.

KILN for tin-ore. The place where the tin-ore is roasted in order to burn away the mundic, and other sulphureous matters that are mixed with it, is called the *tin-kiln*. This is of a very plain structure; its hearth or floor is made of one large stone, and this is covered with another, supported at six inches height above it. The uppermost has a hole in the middle, through which the ore is poured on the under one; and when it is distributed over it in a bed of three or four inches thick, it is burnt by means of a fire of furze bushes kept underneath, and communicating with the space between the two stones by an aperture behind; the lower stone not reaching the wall by six inches.

When the sulphur is all burnt away by the fire, and the flame is no longer blue, the whole bed of roasted ore is thrust off the stone by the rake into the aperture behind, through which it falls into the open fire. The fire is kept up with new bushes, and there is a new bed of ore thrown in at the hole above. Thus the fire is kept up day and night, and supplies of fresh ore made through the hole by the black tin brought from the buddles of washing troughs. When the lower part of the furnace is filled up with the ore thrown into it, there is a hole behind the kiln, through which this ore, and the coals and ashes, are all raked out together, and left in the open air to cool; and the whole mass thus raked out, will sometimes be several days in cooling, the mixture of coals among it keeping it red-hot for a considerable time. When it is taken away from behind the furnace, it is walked again before it is put into the melting furnace. It is observed, that the different ores require for this last operation a different proportion, and different sort of fuel. The moor-tin, that is, such ore as is dug up in the moory countries, melts best with moor-charcoal charred; but that dug on the hills is found to run best with a mixture of charcoal and peat in equal quantities. The stones used for the kilns are always moor-stone. Phil. Trans. N^o 69.

KILN, in Ship Building, a convenience for boiling or steaming planks to make them pliable. A boiler-kiln is either made of sheet-copper, bottom and sides rivetted together, or the bottom of sheet-copper and the sides of lead, rivetted and soldered together. This is fixed in a body of brick-work, and under each end, or in the middle, are furnaces to cause the water to boil after the planks are in. The upper part, to preserve the steam and facilitate the boiling, is inclosed by shutters, opening by hinges and small tackles.

Dimensions of a Copper Boiler

	feet.	in.
Long - - - - -	40	0
Broad at the ends - - -	4	3
----- middle - - -	6	0
Deep - - - - -	2	10

And weighed 55 cwt. 3 lb.

A steam-kiln is a trunk composed of deals grooved and tongued together edgeways, and is from three to four feet square, and from 40 to 60 feet long, and has a door at each end. It is confined together by bolts driven through the sides at certain distances, which answer the purpose of bearers, whereon the planks rest while steaming. It is supported, about four feet above the ground, upon a strong framing of wood. Underneath it, in the middle, is fixed, in brick-work, a large copper or iron boiler, or, which is better, one towards each end; the steam from the boilers, issuing into the trunk wherein it is confined, enters into the pores of the plank, and renders it very pliable.

Laboratory

LABORATORY is a place furnished with chemical apparatus, and entirely devoted to the different operations of chemistry, whether on the scale of chemical manufacture, or for the purpose of experimental research. In the present article, however, we shall confine ourselves to the latter, since it is more proper to describe the apparatus used in the large way under the manufacture of the respective articles. Although many of the most distinguished labourers in chemical science have been content with such apparatus as they have made themselves, or converted from the common domestic utensils; it must, nevertheless, be obvious, that they would have succeeded better with well contrived and appropriate apparatus, and their researches would, in all probability, have been much more extended.

Every chemical experimenter will find a considerable advantage in so much mechanical talent, as will enable him to make, or repair at least, the most common of his apparatus. For this purpose he should possess a set of mechanical tools, such as a lathe and vice, with files and rasps for metal and wood. The tools for making screws, as well in the lathe as by the *screw-plate* and *taps*, will also be necessary. To these should be added a small forge, anvil, and hammer, for the purpose of forging small articles. A set of brazier's and tinman's tools will be found very useful, and a little experience will enable the operator to make any article of tin or copper, which is not very complicated. In addition to the above, the glass-blower's lamp and bellows will be of essential service for sealing and bending glass tubes, and other purposes.

Some of these may appear unnecessary, especially in large towns, where the different artists may be found, but it will be strongly in the recollection of all who have had occasion to get apparatus made, that they can seldom get them constructed to their wish, although they stand by the artist. The want of proper tools, and a little mechanical dexterity, have frequently prevented or put an end to experimental investigations of considerable importance. Independent of the apartment containing the mechanical apparatus, the chemist will require at least one distinct room for a laboratory. Two rooms, however, should be employed when it is convenient. The principal room of the laboratory should be on a ground floor, for several reasons. A furnace for great heat should be in a low room, in order to have the greatest length of chimney. The ash-pit of this furnace should terminate in a cellar under the laboratory, in order that the air may enter perpendicularly, and of the lowest possible temperature. See FURNACE.

That side of the laboratory allotted for furnaces should have an arch projecting into the room about three or four feet, and of such height that a person may freely walk under

it. In the highest part of this arched portion must be an opening into a chimney distinct from the rest, and built up in the same stack.

It will be found more convenient to use portable furnaces for most purposes, having none fixed but for producing very great heats, upon a larger scale, and what are generally denominated melting furnaces.

The iron chimney of the portable air-furnace may be carried to any height, and placed under or within the chimney, used for the escape of smoke and vapours.

A chimney with a funnel may, in the same way, be placed over the mouth of the portable blast furnace, invented by Mr. Aikin. This furnace may be so contrived that when the body of it is removed, the base may form a forge hearth, which will be found very useful. For the varieties of furnaces used in the laboratory, see FURNACE.

On another side of the laboratory must be placed a stone trough or sink, joined to a tub or cistern of water, which can be filled and emptied at pleasure, by means of a stop-cock over it, and a plug in the bottom. Over the sink-stone should be suspended a rack for holding bottles and glasses to drain after washing. On the same side may be placed a large block of wood or stone, for the purpose of holding a mortar or anvil occasionally.

A third side of this room must be occupied by cupboards and shelves, for holding the different apparatus of glass and earthen ware, and for the different substances hereafter to be mentioned.

The fourth side, which should be the lightest, must be provided with a table the whole length of this side, in the front of which, down to the floor, should be a number of drawers for holding all the dry substances. This table is for making the experiments upon, and for holding the apparatus in use at any time.

If possible, every laboratory should be joined to a second room, however small it may be, in which to perform the very nice and delicate experiments, and for keeping a few books, and choice instruments of metal, such as balances, &c. This room should be kept very clean and dry, and as free as possible from steam and the fumes of acids.

If any part of the furniture require to be painted, the paint should be made with sulphat of lead, since it is not acted upon by acids. This substance has been used by Dr. Henry not only for this purpose but for repairing broken glass and labelling bottles. The following are the most particular apparatus with which a laboratory should be furnished.

Mortars.—These are of various kinds, cast-iron, bronze, steel, and Wedgewood ware. The cast-iron mortar is generally used for vegetable substances, and such as are not liable to grind off the iron. The hardness of this instrument is

much increased by casting the interior surface upon a metal mould, of the greater weight the better.

The hardness of the bronze mortar, which is generally used for the same purposes, may be increased by the same means.

The steel mortar is used for reducing very hard minerals into small bits, fitted for grinding in the mortar of agate. It consists of a cylinder of hardened steel, with a flat bottom, and a pestle of the same made to fit the mortar, accurately, from top to bottom. It is used by putting the pieces of the mineral into it, and striking the pestle with a hammer. By this means it can be reduced into tolerably small particles, without grinding off any portion of the mortar.

Hardened steel mortars of the common shape would be of great use, but it would be difficult to harden so large a mass without cracking. It might perhaps be made by welding a plate of cast steel upon a thick piece of iron, and afterwards working it into the required shape, and polishing it in the inside. If the substance is not very particular, it may be ground in a mortar of Wedgewood ware. If, on the contrary, it be very hard, the matter from the mortar will be liable to be mixed with the powder. In this case the agate mortar is much to be preferred; some stones are, however, so hard as to act upon the agate. In this instance, the matter to be ground should be weighed before and after grinding, and the increase of weight may be safely deemed loss, and allowed for in the analysis accordingly.

Balance.—This instrument is of great importance to the analytical chemist, and ought to weigh 100 grains to the $\frac{1}{4}$ th of a grain. A very masterly account of the principles and construction of the balance will be found under the article **BALANCE**.

It will be almost unnecessary to observe, that so delicate an instrument should be kept in a separate apartment from the laboratory where fumes of acids do not prevail. It should be closely shut up in a glass case having a sliding door in the front. The strings to which the scales are suspended, should be of fine gold or silver cord, and the scales of silver or platina, and very thin. One of the scales should be provided with a loose pan of very thin platina, and balanced with the other, for the purpose of holding the substance to be weighed. The weights for chemical substances should be reckoned in, and marked with grains and decimals of grains.

Lamp.—This valuable instrument is a very great improvement upon the sand-bath. Its heat is regular, and may, by means of the concentric wick, be made of sufficient intensity for most purposes. Its greatest advantage, however, consists in the facility with which it can be applied or withdrawn without loss of time. See **LAMP**.

For nice and delicate purposes, where the heat of the lamp is required, alcohol, instead of oil, gives an intense and steady heat, and is not very expensive when a proper vessel is used for burning it. The latter kind of lamp is particularly adapted for a public lecture.

Fig. 1. Plate XVI Chemistry, is a stand supporting the lamp, and at the same time the substance to be heated, and the connecting apparatus A B is a frame of wood. F a pillar of wood or iron, smooth and cylindrical throughout, so as to admit of the sliding rings, such as *g*, to move freely without shaking. C is the Argand lamp, having a chimney at *c* of iron. This chimney consists of two concentric tubes, connected together by small wedges of baked clay, or some other incombustible substance which is a bad conductor of heat. This contrivance not only economizes the heat, but keeps the outer tube so cool, that it may be taken hold of with the fingers. In this lamp the wick is raised by the screw,

instead of the rack, which is performed by turning the chimney round.

The funnel-shaped ring D is an improvement upon the common ring used for supporting the retort. It consists of a number of conical hoops, one fitting upon the other, so as to hold different sized retorts. The smallest hoop is about two inches in diameter, and the largest, which is attached to the sliding part, about five inches. The conical surface directs the heat to the retort, which on the common plan only serves to annoy the fingers and face of the operator, and at the same time heats the neck of the retort, where the condensation of the vapour should take place: *f* is a retort supported by the ring: *g* is a slider, having two prongs at *p* to keep the retort from falling sideways: E is a receiver to receive the contents of the retort, which may be either used alone, or with Woulfe's bottles *a, b, c*, hereafter to be described. G is a stand, with three inclined prongs of wood to support receivers of different sizes, and which may be placed at different elevations by means of the screw *n*.

Retort.—**Fig. 2.** This is a chemical utensil of very ancient origin, and is the most simple apparatus for distillation. Retorts are of glass, earthen-ware, and metal. Those of glass are sometimes of green glass, particularly when such heat is employed in the naked fire, as might soften the more fusible white glass. Those of flint-glass should be as thin as possible, in order to avoid breaking by an unequal expansion. When the retort is provided with a glass stopper, as at *a*, it is said to be tubulated.

This appendage is necessary only, when some fluid, such as an acid, has frequently to be added, or when it would be difficult to get the materials into the mouth of the retort. In order to add any fluid from time to time while the process is going on, the vessel (**fig. 3**) called an *acid holder* is made to fit in the place of the stopper of the retort, the part *d* being ground to fit the same. The acid is put into this vessel, and let into the retort, by a little at once, through the glass stop-cock *c*.

When the retort is used for purposes of distillation, the neck is fitted or luted into the neck of the receiver (**fig. 4**) This receiver is used for the distillation of liquids, the vapours of which are easily condensable, such as water or alcohol. When the vapours, coming over, are accompanied with elastic fluids, which are incondensable, the receiver (**fig. 5**) is better adapted. If the elastic fluid be of no importance, and inoffensive, it may escape at the conical stopper of the latter vessel every time the pressure is sufficient to raise it. It is, however, sometimes necessary to collect the gaseous fluid. In this case the bended tube (**fig. 6**) is put into the place of the stopper (**fig. 5**), the other end terminating in a pneumatic apparatus where the gas is collected. In the distillation of very volatile liquids, such as ether, it is sometimes necessary to remove the receiver to a distance from the retort, by placing between them an intermediate vessel, (**fig. 7**) called an *adopter*. The receiver (**fig. 8**) is employed for collecting the product of different degrees of strength by the application of the bottle *b*.

In the distillation of substances, which require a greater heat than glass will bear, earthen retorts are employed. They are of the same shape with those already described, and should be made of the materials with which crucibles are made. This sort of retort is generally used for the distillation of phosphorus. If its texture be not close, the phosphorus will escape in vapours through the pores. This, however, may be prevented by covering the surface with some glazing material. Iron retorts, from their great firmness, are well adapted for distilling such substances as will have no

chemical action upon them. Hence they are unfit for distilling sulphur, phosphorus, and acids, but are extremely proper for ammonia, mercury, and pitcoal. A retort of lead is used for the distillation of fluoric acid, owing to that acid combining with the filices of glass.

Woulfe's Apparatus.—In the distillation of substances which are merely to be raised into vapour by heat and condensed by cold, the retort, or still, with the receiver and the proper means of producing cold, are the only apparatus necessary. There is another distinct branch of distillation, in which the product is a gas, which is incondensable at the common temperature, and requires to be absorbed by water, or by some other substance dissolved in that liquid. In these processes, therefore, the temperature and size of the receiving vessels are not of so much importance as the exposure of the gaseous product to the greatest possible quantity of the absorbing liquid. Before the discovery of this most useful apparatus by Mr. Woulfe, from whom it takes its name, the common retort and receiver were used for all purposes. The elastic fluids were in consequence either compressed, and the operator was constantly in danger of being injured by the bursting of vessels, or, to remedy that evil, they were suffered to escape, and he was perpetually annoyed by the suffocating fumes which were set at liberty.

In *fig. 1.* the retort contains the materials for furnishing the elastic fluid to be absorbed by some liquid contained in the receiver E, and the succeeding bottles A, B, C, with their connecting tubes *r, b, t; v* constitutes the *Woulfe's apparatus*. A certain portion of the gas is taken up by the liquid in the receiver E. The excess passes through the tube *r* to the bottom of the liquid into the second receiver, by which another portion of the gas is absorbed. The residual gas passes along the tube *b* to the third receiver, which gives the gas a third chance of absorption. In this way it may be made to pass through any number of bottles, according to the greater or lesser facility with which the gas is absorbed. The last tube *v*, which is provided with a column of mercury, conveys the remaining gas, which is presumed to be unabsorbable, into the atmosphere, or it may be collected by a jar in the pneumatic apparatus. When the gas ceases to be furnished from the retort, in a quantity equal to the absorption in the receiving vessels, a retrograde motion will begin to take place. Atmospheric air will enter at the tube *v*. The liquid in the last receiver will be forced by its pressure into the preceding one, and in the absorption were to become complete, the whole of the liquid would be carried into the first receiver, and from thence to the retort. This evil has been very completely removed by what is called a tube of safety *f, l, x*.

Fig. 1.—The bulb *l* contains as much mercury as will be contained from *g* to *x*, so that when the gas, from defective absorption, accumulates in E, till its force is equal to the pressure of such a column, the excess of gas will bubble through the mercury into the atmosphere. On the contrary, when the absorption of the gas exceeds its evolution, the pressure of the atmosphere, to restore the equilibrium, will cause the mercury to occupy the ball *l*, and common air will bubble through it into the vessel E. Although this ingenious contrivance completely prevents any evil arising from the inequality of internal pressure, it is very objectionable, owing to its delicate structure, on which account it is constantly liable to be broken.

We are indebted to Mr. Knight for a great improvement on the tube of safety. This consists in having a valve of glass, similar to that of the *Nooth's apparatus* (described below), placed between the first and second vessel, so that the liquid in the succeeding bottle can never have a retrograde motion. To this valve there is no other objection than the

difficulty of getting it made in places distant from the metropolis, and its liability to be fast, especially in making crystalline salts, such as the oxymuriat or carbonat of potash.

The same objection which we have made to the tube of safety, we are sorry to say applies to the whole of the *Woulfe's apparatus*. The connecting tubes are with very great difficulty ground into bottles, which makes the apparatus very expensive, and then are so liable to be broken, as to render it frequently useless.

We have before hinted, that the essential part of such an apparatus, is to expose the greatest possible quantity of the gas and the liquid to each other in a given time. In the *Woulfe's* bottles, this advantage does not obtain in so great a degree as might be effected in a simpler apparatus. We shall here subjoin a description of an apparatus of this kind, answering all the purposes to which the *Nooth's* and *Woulfe's* apparatus are separately applied. Although it has not been before made known, it has been used with great success by the writer of this article, and will no doubt be found an acquisition to the experimental as well as the manufacturing chemist.

Fig. 9. Plate XVII. Chemistry, is a representation of the apparatus for the absorption of gases. A is a retort from whence the gas is furnished, connected with the first bottle B, which contains the liquid to be impregnated, and into which the tube *a* is ground, reaching near to the bottom, so that when the gas enters this vessel, the liquid will be raised into the bottle C; at the same time the tube will be constantly filled, with the exception of the space occupied by bubbles of gas passing through it. If the gas is not all absorbed during its passage through this tube, the excess will pass down the tube *b* into the bottle D, which also contains the absorbent liquid. The same takes place in this bottle which is observed in that of B. The liquid ascends into the bottle E, the gas following it as before. The residual gas, should there be any, may either be conveyed into another bottle situated like D, or may be collected in a pneumatic trough, or escape through the tube of safety *e*.

This apparatus was invented for the purpose of making the oxymuriats of the earths, for which it is admirably adapted. The earths which are mixed with the water being constantly at the bottom, if not kept in agitation, the absorption is very slow and imperfect. In this apparatus no agitation is necessary. The earth, which is at the bottom of the vessels B and D, is first raised into the tubes *a* and *c*, and becomes as much exposed to the gas as any part of the liquid medium. The tubes *a* and *c* are each about two feet long, but they do not require to be so long for most experiments of this kind. Their diameter is about $\frac{1}{4}$ inch, so that in the course of about one minute, no less than about nine ounces are brought in contact with the gas, independent of the circular surfaces in the bottles.

In the common sized *Woulfe's* bottles, the tubes through which the gas enters seldom dip more than three inches into the fluid, so that we may safely rate the apparatus proposed as equal to at least eight of *Woulfe's* bottles. These bottles are the same with those of *Woulfe's*; the tubes are much simpler, and being stronger are less liable to break. Another great advantage is that of its not requiring a tube of safety. The great facility with which it can be applied to all the purposes of the *Nooth's* apparatus, as well as the *Woulfe's*, and with much more effect, will be soon appreciated. Under the article *Woulfe* will be found the description of a differently constructed apparatus. See *Plate V. Chemistry*.

Nooth's Apparatus.—This is represented in *fig. 10. Plate XVI*. It consists of three vessels fitted together by

ground joinings. It differs in its use from the Woulfe's, in being solely adapted for impregnating water and other bodies, with such gases as are disengaged from their combinations without heat, such as the carbonic acid, and sulphuretted hydrogen. The lower vessel A contains the substance from which the gas is obtained, such as carbonate of lime; the sulphuric acid being introduced occasionally at *d*; the gas enters the vessel B through the glass valve *a b*. This is magnified in *fig. 12*. The tubes *b* and *d* are at first in one piece and ground into the part *a c*; the portion *c* is then cut away, to make room for the hemispherical valve, the under side of which is ground flat, to fit the end of the tube *b*. The valve, on being raised by the gas, instantly falls and prevents the water from descending into the lower vessel. The air then enters the liquid in B, *fig. 10*, through small holes to disperse it as much as possible. When the gas accumulates in B, a portion of the liquid is driven up into the vessel C, the bubbles of air following it tending still more to promote the absorption. The air in C, if not absorbed, will at certain intervals raise the conical stopper *e*. This stopper should be so heavy as just to rise before the vessels would burst, and should be so conical as not to flick in the least degree. After the liquid is impregnated it is drawn off at the cock D.

Fig. 11, is a simpler and better apparatus for this purpose, invented by Dr. Hamilton. It is simpler, because the vessels are fewer, and the valve, which is complicated and liable to be fast, is dispensed with; and it is better because the gas comes in contact with more of the liquid in a given time, and consequently the absorption is effected sooner. The gas is furnished by the retort B, ground into the vessel A. From the latter the absorbing liquid is raised into the vessel C, till the air bubbles go through it, and if not absorbed passes out at *d*. This apparatus wants nothing more than a tube of greater length, for the gas to pass through, to make it complete.

In comparing the two last with that of *fig. 9*, the latter will be found much superior even to that of *fig. 11*.

Gasometer and Gas Holder.—The difference between these two vessels, consists merely in one having the means of measuring the quantity of gas which it contains at any time, and the other not, while both are employed as gas holders.

The gasometer was made a very expensive and magnificent apparatus by the celebrated Lavoisier, at the time he prosecuted his experiments upon elastic fluids. This instrument, much simplified, we shall describe in *fig. 13*, *Plate XVII*. A is a vessel containing water or some other liquid, which will not be acted upon by the gas to be held in it. B is a vessel inverted in the vessel A, and capable of moving up and down in it. E and F are cords by which the vessel B is suspended, the weights and pulleys being concealed in the tube C D.

Fig. 14 is a section to shew the interior parts of this apparatus. K L is an interior vessel of the same shape, with the vessel B folded to the bottom of the vessel A, so that no water or other liquid in A can communicate with the inside of it. This is done for the sake of using less of the liquid employed, which in the mercurial gasometer is very desirable, as well for the sake of economy, as making the apparatus more portable; *a* is a pipe passing through the middle of the vessel K L, and communicates with the tubes *o* and *d*. The air is introduced at the stop-cock *e*, and passing along the pipes *o* and *a*, raises the vessel B, which is counterpoised by the weights *r* and *q*. These weights are conducted down the middle of the tube C D, by the small pulleys *x x* and *y y*. The tube *d*, which, with that of *o*, is common to the tube *a*, is to let the air out of the gasometer at the stop-cock *f*, so that the air passes through *a*, both in its entry and its exit: *g*, *fig. 13*, is a flexible tube, serving to con-

duct the air to a pneumatic trough for examination, or for using the blowpipe when the vessel contains oxygen. This apparatus is provided with a graduated scale G, which tells the number of cubic inches contained in it. It is this scale which constitutes it a gasometer, without which it would be simply a gas-holder.

The mercurial gasometer is on the same plan with the above, but the materials must be unsuceptible of the action of the mercury. The vessels are generally made of cast-iron. The outer and the fixed inner vessels may be cast in one piece. The moveable vessel may be of the same metal, or of glass. The pipes must be of wrought iron, and accurately ground into the cast iron. Two gasometers with water, and one with mercury, will be indispensable in experiments in gaseous chemistry.

A very ingenious apparatus, answering the common purposes of gas-holder and gasometer, and in many instances the pneumatic trough, has been invented by Mr. Pepys. It consists of a tin vessel A, *fig. 15*, and a pan or tray B connected with it by pillars. The pipe *a* opens into the middle of the tray, and proceeds in a contrary direction near to the bottom of the vessel A: *v* is another pipe which also communicates with the tray, and just enters the vessel A: *r s* is a glass tube cemented firmly into two brass sockets, which communicate with the top and bottom of the vessel A. This tube is graduated, and shews how high the water stands in the vessel, and consequently tells the quantity of air contained in it. The vessel A is first filled with water by opening the cocks *a* and *v*, and shutting that of *n*, C being closed at the same time. The tray is now filled with water, which descends through the tube *a* into A, while the air in the same escapes at the opening into the tray, from *v*. When the vessel A is full of water, the cocks *a* and *v* must be closed, and the plug may be taken out of C. If the vessel and pipes be air-tight above, no water will be discharged at C, since this pipe is inserted at such an angle into A, that the lowest part of the outer end is higher than the highest part of the inner end. The next thing is to fill the vessel with gas, and for this purpose the neck of a retort, or other tube from which the gas is to proceed, should be introduced at *c* till it passes the inner end of the same. The gas will rise in bubbles into the upper part of the vessel, while the same quantity of water will run out at the pipe C into an open vessel placed under it. When the water ceases to run out, and air-bubbles escape at C, the tube from whence the gas was furnished may be withdrawn, and the screw-plug put in its place.

In order to transfer the gas from this vessel into a jar, the tray must be filled with water, and also the jar, which must then be placed over the aperture from *v*. On opening the stop-cock *v*, that of *a* being previously opened, the air will ascend into the jar, while the same quantity of water will descend into the vessel A, to supply its place.

This apparatus may be used for several other purposes. A bladder may be tied to the stop-cock *n*, which being opened at the same time *a* is opened, the bladder will be filled with the gas. A flexible tube may be screwed on the same stop-cock for making experiments with the blow-pipe. The gasometer, *fig. 13*, will be found better for the blow-pipe, on account of the equable pressure in the apparatus last described.

Pneumatic Trough—This is a simple trough or cistern made of tin or copper japanned, and is used for collecting different gases. The size is generally about 18 inches long, 12 wide, and 12 deep. *Fig. 16*, *Plate XVI*, represents this trough. A is a sliding shelf which can be taken out. It is formed of two plates laid together; the under plate is made so concave, that when the convex side touches the upper plate in the middle, they are distant at the edges about one inch.

A rim being soldered round the two gives the shelf the appearance of a solid, concave on the under side and flat on the upper side.

Any gas coming from the retort B, passing under the shelf in any situation, must be determined to the round hole in the middle, which is about half an inch wide. The trough, when used, is filled with water about an inch above the shelf, the jar C being filled with the same, and placed over the aperture through which the bubbles ascend. The stand D, having a foot of lead or iron, will be found very useful for supporting a retort or other vessel in these experiments. When a number of vessels are occupying the shelf, and frequently some are very tall, and of small diameter, it will be found necessary to support them to prevent their being thrown over. This may be effected by having a number of supporters of different sizes, such as A. This is better represented in *fig. 17*. At *d* is a socket to fit the pins which surround the shelf; *n, o*, are springing claws to embrace the glass.

In making experiments upon gases, a number of vessels, such as *fig. 18*, will be necessary. These are generally called eudiometer tubes, some of them are graduated into cubic inches, for the purpose of measuring the volume of gas used, or resulting from any experiment. See EUDIOMETRY.

Besides the trough already described, which is used with water, it is necessary to be provided with one for mercury. Indeed the latter is absolutely indispensable when the gases, which are the subject of experiment, are absorbable by water: such as the muriatic acid gas, and ammoniacal gas.

Fig. 19, is a view of the mercurial trough: it is generally made of a solid block of some hard wood, or of marble; or it may be made much neater, and with less labour, of pieces of wood joined together, closely and firmly by iron screws. The first cavity, *a e b*, may be about eight inches long, four inches broad, and one inch in depth: the second or lower cavity, *d*, should be about $6\frac{1}{2}$ inches long, $1\frac{1}{4}$ wide, and the same depth: *c* is a smaller cavity, about $\frac{3}{4}$ of an inch wide, $1\frac{1}{2}$ long, and one inch deep. The cavity *d* is intended to receive the glass jar, *fig. 20*, for the purpose of filling it with mercury: *a, b*, are small cavities in which to introduce the fingers for the purpose of raising the jar when full of mercury. The cavity at *c* is to place the inverted jar over, for the purpose of introducing any gas into it. The side *a c* answers as a shelf to rest the inverted jars upon: *fig. 21*, is a ring of iron, with a leg to slip into holes on the side of the trough, for the purpose of supporting the jars, which would otherwise be liable to fall on account of their small base.

Eudiometer.—Formerly the use of this instrument was confined to the analysis of the atmosphere. It has now, however, become of great importance in gaseous chemistry, and has been considerably improved within these few years.

In order to ascertain the nature of, and to distinguish the different gases, chemists have generally recourse to some substance capable of absorbing the gas under examination. The eudiometer is the vessel which contains, or communicates with the substance which is to absorb the gas, and the tube being graduated marks out the quantity absorbed, and shews how much of that particular gas was present.

The first instrument of this kind, adapted to general purposes, was invented by Dr. Hope, of which a description will be found under EUDIOMETRY. Under the same article will be found Mr. Davy's eudiometer for the analysis of the atmosphere.

Mr. Pepys has lately invented a very good eudiometer: it differs from Dr. Hope's in the bulb, which holds the absorbing liquid, being an elastic gum bottle instead of glass.

A glass neck is tied into the neck of the bottle, into which the graduated tube is ground. When this eudiometer is used, the elastic bottle is filled with the absorbing liquid (lime water, for instance), and the tube filled with the gas under examination (supposed to be carbonic acid), introduced into the neck.

On agitating the liquid to mix it with the gas, as the absorption goes on, the elastic bottle collapses, by the atmospheric pressure, and the liquid occupies the place of the absorbed gas in the tube.

The only objection to this eudiometer is its want of flexibility, and this varying under different circumstances, so that the density of the contained air can never be accurately known. The writer of this article has done away the above objection, by using a bag of oiled silk instead of this elastic gum bottle. The silk must be very well coated, and the coating completely dry.

The eudiometer of Volta, which is found very useful in the presence of the electric machine, is also called the *detonating jar*. It is used with oxygen to detect the presence of hydrogen, and *vice versa*. This instrument, *fig. 22*, consists of a very thick glass tube A B, having two bits of metal *a, b*, passing into the tube opposite to each other, the inner ends being separated from each other a small distance, so that an electric spark passing between them, may be capable of inflaming hydrogen with oxygen.

The gas to be examined is introduced into this jar, and the electric spark passed through it. If hydrogen and oxygen be present, in sufficient quantity, they will explode, forming water, and producing a diminution of volume equal to the original bulk of gases which have entered into combination. In the explosion of these gases the water or mercury is apt to be thrown in various directions by the concussion. We are indebted to Mr. Pepys for an ingenious method of preventing this evil. The tube A B is secured to the iron stand D E by means of a socket C. D is an iron tube containing a spiral spring, similar to that of the spring steel-yard. The rod *d*, which acts upon the spring, is fastened to the foot E, which is so heavy as not to be raised by the force exerted upon the spring. When the detonation of the gases takes place, the force is exerted equally upon the instrument and the liquid, in which it is immersed, when they are both at liberty. Instead of being all exerted upon the latter, it causes the tube to rise, the spring in the socket D giving way, and thus prevents the liquid from being displaced. All the gaseous bodies containing hydrogen can now be analysed by this instrument. Dr. Henry has discovered that ammonia, which does not appear combustible, can be exploded with oxygen: its hydrogen forming water with that substance. See EUDIOMETRY.

Evaporating Vessels.—These are of metal, earthen-ware, and glass. They are generally made broad and shallow, as seen in *fig. 23*, in order to expose a greater evaporable surface. During the evaporation of any liquid, a current of air should constantly be passing over its surface. This object can be easily attained by placing the vessel under the mouth of a chimney into which there is a considerable draught. By this means also the vapour is prevented from coming into the room.

These vessels are of silver for expelling the water from alkalis, and of glass, or Wedgewood ware, for acids and some solutions of salts.

Sand and Water Baths.—The sand bath, although superseded by the Argand lamp, for distillations in the small way, is, nevertheless, very useful for digesting substances subjected to solution, and for evaporation. Its heat is much more regular than the naked fire, but it may sometimes be too

hot for substances which are liable to be decomposed, such as infusions of vegetable or animal matters. The most useful sand bath is made of a plate of cast iron, under which the flame of a fire plays, and a rim of cast or wrought iron laid upon it and filled with fine Calais sand.

A sand-bath frequently consists of an iron dish or pan made to fit the mouth of a furnace. See FURNACE.

When an uniform heat, not higher than 212° of Fahrenheit, is required, or when it will be sufficient, the water bath is found highly useful. Instead, however, of placing the substance to be heated in a vessel of boiling water, which was formerly the case, the bath may be heated with steam at any distance from the boiler. This bath may be a vessel of any shape, having a cavity for steam on the outside, thickly covered with flannel, or any bad conductor of heat, and the inside filled with sand. This bath is admirably fitted for the evaporation of solutions of animal and vegetable substances, and for drying precipitates and other substances liable to be decomposed or changed by great heat.

Mattress.—This is a vessel used for making solutions of substances. It is generally of a spherical form, flattened at the bottom, as seen in *fig. 24*, having a long neck to allow the fluid to condense and return into the vessel. This useful apparatus is made of glass, and thin at the bottom, in order to prevent its breaking. The common Florence flask is a good substitute for the mattress. A smaller vessel of this kind is used for boiling a less quantity of any liquid; these are called *proof glasses*. See *fig. 25*.

Precipitating Glasses.—See *fig. 26*.—These are tall cylindrical vessels, in which precipitations are performed, in order to collect the separated matter into less room. In washing precipitates it is found, that when hot water is poured into the glass, if the bottom be thick it is liable to break. This evil has existed more or less in all the precipitating glasses in general use. In making this vessel at the glass-house, the part to form the bottom should be blown out thin, like the mattress, and then pushed inwards to make it stand firmly. Very small vessels in this shape are used for small quantities of any substance. These are called *test glasses*.

Gas bottles, such as *fig. 27*, are vessels for obtaining hydrogen, carbonic acid, and other gases. The materials, such as water and zinc filings, are introduced into the bottle A. The sulphuric acid being put into the bottle B, the plug *b*, which is ground into the neck *d*, can be raised to let in the acid as it may be wanted. The gas escapes through the crooked tube C, which may be put under the shelf of the pneumatic trough.

Funnels are used generally for filtration; they are commonly, and always ought to be ribbed for this purpose, in order to form channels between the paper and the glass, which greatly facilitates the process. In lieu of a ribbed filter, it is common to place a number of straws, or pieces of glass, between the paper and the vessel, which answers very well.

The separatory funnel, *fig. 34*, is used for separating fluids, such as water and oil, which do not mix from the difference in specific gravity.

The following articles are also essential to the laboratory, which it will be unnecessary to describe.

Thermometers and a barometer. Bottle for ascertaining the specific gravity of liquids.

A common still to furnish distilled water.

A small one of silver for nice purposes.

The different blow-pipe apparatus, with platina, spoons, and leaf platina.

A silver crucible, and one of platina.

Crucibles and crucible stands of earthen ware. See *figs. 29, 30, and 32*.

Muffels and cupels. See *figs. 28 and 33*.

Iron retort and jointed tube for procuring oxygen gas. *Fig. 35*.

Glass jars of different sizes for collecting gases.

Filtering paper, and papers coloured with litmus, turmeric, and red-cabbage.

A general assortment of glasses, to filter liquids into, &c.

An assortment of earthen vessels for common purposes. Those made of the same materials as the soda water bottles are to be preferred.

Capules of glass, and watch-glasses. The former may be cut out of broken retorts and receivers with a small hot iron.

Glass tubes of different sizes, and a spirit lamp for bending them.

Glass and porcelain rods and spoons for stirring acids, &c.

Jars of glass and earthen ware, with grooves round the top, for luting them closely from the air. These should be used for containing salts in crystals.

Ruled paper for labels; copal varnish to cover the same, to keep off the dampness and fumes of acids.

Sheets and wires of different metals.

Silk and thread of different strength.

Stands made of wood or rushes, for supporting vessels with round bottoms.

Iron ladles of different sizes.

Hammers, shears, and plyers.

Corks, bladders, and sponge.

Tongs of various forms.

Files, diamond, and magnet.

Lutes, linen, cloth, and tow. See LUTE.

The following philosophical apparatus;

Air-pump for condensing and exhausting.

Syringes, microscope, and burning lens.

Electric machine and Galvanic apparatus.

Zinc plates and wire, for minor experiments.

Hydrostatic balance and hydrometer.

We shall conclude this article with a list of the chemical substances necessary to be kept in a chemical laboratory. These are divided into wet and dry substances. The first of these must, of necessity, be kept in well-stopped bottles. The latter should also be kept in bottles, the necks of which should be wider than those for liquids.

Substances in common use should be kept in larger quantity than those which are kept as mere specimens, or only used occasionally and in small quantity.

Liquids in common Use.

Sulphuric acid, pure.

————— common.

Nitric acid, pure.

—————, common.

Muriatic acid, pure.

—————, common.

Acetic acid.

Water saturated with ammonia.

Solution of potash.

————— carbonat of potash.

————— potash.

————— super-carbonat of potash.

—— soda, and carbonat of soda.

———— carbonat of ammonia.

Lime water.

Distilled water.

Alcohol, pure.

——, common.

The bottles in which the above are kept should hold from a pint to a quart each.

After a change of temperature in the air from cold to hot, we find at the tops of bottles, about the stopper, a quantity of the liquid which has distilled up to the stopper, and been forced out by the expansion of the air in the bottle. This is very troublesome, especially with acids, and may be remedied by giving to the mouth of the bottle a slight funnel shape, which forms a recess for the liquid.

The following are the dry substances in common use.

Oxyd of manganese, and common salt.

Filings and rods of iron, tin, zinc, copper, and lead.

Chalk and powdered marble.

Quick lime, pipe clay, and sand.

Magnesia, common and calcined.

Sulphurets of potash, iron, and lime.

Isinglass and nutgalls.

Brazil wood and turmeric.

Calcined plaster of Paris, and bone ashes.

Black flux and white flux, See FLUX.

Charcoal powder and saw-dust.

Sulphat of lead, as a body for lutes.

Nitre in crystals.

Borax and alum.

The following are bodies in solution; used as tests and kept in small quantities, in bottles from one to two ounces in size. The bottles should be shaped at the mouth as above recommended, and the diameter should be half the height in the cylindric part.

Sulphat of potash.

foda.

alumine.

ammonia.

magnesia.

zinc.

silver.

Oxy-sulphat of iron.

Nitrat of potash.

—— foda.

—— barytes.

—— strontian.

—— lime

—— silver.

—— copper.

—— lead.

—— bismuth.

Muriat of potash.

—— foda.

—— barytes.

—— strontian.

—— lime.

—— ammonia.

—— gold.

—— platina.

tin.

cobalt.

Oxymuriat of mercury.

Phosphat of foda.

—— ammonia.

Fluat of potash.

—— ammonia.

Borat of foda.

Carbonat of potash.

—— foda.

—— ammonia.

Acetat of potash.

—— barytes.

—— strontian.

—— alumine.

—— silver.

—— copper

—— lead.

Oxyacetat of iron.

Oxalat of foda and ammonia.

Succinat of ammonia.

Tartrat of ammonia.

Prussiat of potash and iron.

—— lime and iron.

Pure gallic acid in alcohol.

Infusion of galls in alcohol.

—— of litmus.

Acetic acid, pure.

Hydrosulphuret of potash.

The following substances should be kept in the solid state, and free from the contact of air and moisture.

Sulphat of iron kept in alcohol.

Muriat of lime.

Oxymuriat of potash.

Barytic earth.

Strontian earth, and all pure earths.

Pure potash.

—— soda.

Potassium and sodium, kept in naphtha. See POTASSIUM and SODIUM.

Sulphurets of potash, iron, and lime.

Phosphuret of lime.

Phosphorus.

Pyrophorus.

It is also proper that the chemist should possess as great a variety of all the known chemical bodies as possible, both simple and compound. They are worth possessing even as a matter of curiosity. But they will be highly valuable in giving a familiar knowledge of the different substances which the experimentalist may expect to meet with, and enable him to distinguish them from what may be new.

Lac

LAC, or LACCA, *Gum*, as it is commonly, though not very properly, denominated, because it is neither a gum nor a resin, is a kind of compound substance, prepared by the female of a minute insect, called by some *Coccus Lacca*, and by others *Citermes Lacca*, which is found in several species of trees in the East Indies, and particularly on the banyan-tree (*Ficus indica* and *religiosa* of Linnæus), several species of *Mimosa*, and the *Bilher* on *Rhamnus jujuba*. These insects are nourished by the trees on which they are produced, and fix themselves upon the succulent extremities of the young branches; and around their edges they are environed with a spissid sub-pellucid liquid, which seems to glue them to the branch. It is the gradual accumulation of this liquid, which forms a complete cell for each insect, and is what is called Gum Lacca. When the cells are completely formed, the insect is in appearance an oval, smooth, red bag, without life, about the size of a small cochineal insect, emarginated at the obtuse end, full of a beautiful red liquid. When the eggs are hatched, the young insects, or grubs, first feed upon the red liquid above-mentioned, and when this is expended, they pierce a hole through the coat that invests

them, and move off one by one, leaving their exuvix behind, which are the white membranous substance found in the empty cells of the Stick lac. The accumulation of lac appears in the economy of this insect to be the substance that answers the double purpose of a nidus and covering to the egg or insect in the first stage of its existence, and of food for the maggot in its more advanced state. The lac is formed into complete cells, finished with as much regularity and art as the honey-comb, but differently arranged. The flies are invited to deposit their eggs on the branches of the trees by besmearing them with some of the fresh lac steeped in water, which attracts the fly, and gives a better and larger crop. For a particular description of these insects, and their cells, we refer to the papers of Mr. James Keir, of Patna; Mr. Robert Saunders, surgeon, at Boglepore, in Bengal; and Dr. Roxburgh, of Samulcotta, in the *Philosophical Transactions*, vols. lxxi. lxxix. and lxxxix. Lac is a staple article of commerce in Assam, a country bordering on, and much connected with, Thibet, which furnishes the greatest quantity of that in use; and it is also found upon the uncul-

tivated mountains on both sides of the Ganges. The only trouble in procuring it is that of breaking down the branches, and carrying them to market. The price in Dacca, in 1781, says Mr. Kerr, was about 12s. the hundred pounds weight, although it was brought from the distant country of Assam. The best lac is of a deep red colour. If it is pale, and pierced at top, it is depreciated in value, because the insects have left their cells, and consequently they can be of no use as a dye or colour; though they may be probably better for varnishers. Of lac there are four kinds known in commerce: viz. 1. *Stick lac*, which is the lac in its natural state, from which all the others are formed. This is obtained in pretty considerable lumps, with much of the woody parts of the branches on which it is formed adhering to it. 2. *Seed lac*, which is the former broken into small pieces, garbled, and appearing in a granulated form. 3. *Lump lac*, which is *seed lac* liquefied by fire, and formed into cakes. 4. *Shell lac* is the purified lac, or the cells liquefied, strained, and formed into their transparent laminæ. Lac is brought into this state, or purified, by the following process. It is broken into small pieces, and picked from the branches and sticks, and then put into a sort of canvas bag of about four feet long, and about six inches in circumference. Two of these bags are in constant use, and each of them held by two men. The bag is placed over a fire, and frequently turned till the lac is liquid enough to pass through its pores, when it is taken off the fire, and squeezed by two men in different directions, dragging it along the convex part of a plantain tree (*Musa paradisiaca* of Linæus), prepared for the purpose: while this is doing, the other bag is heating, to be treated in the same manner. The mucilaginous and smooth surface of the plantain-tree seems peculiarly well adapted for preventing the adhesion of the heated lac, and giving it the form, which enhances its value so much. The degree of pressure on the plantain-tree regulates the thickness of the shell, and the quality of the bag determines its fineness and transparency, upon which its value depends.

The lac is applied to various purposes by the natives in India. A great quantity of the *shell lac* is consumed in making ornamental rings, painted and gilded in a variety of tastes, to decorate the arms of the ladies; and it is formed into beads, spiral and linked chains for necklaces, and other female ornaments. It is also used for sealing-wax. For this purpose, take a stick, and heat one end of it upon a charcoal fire; put upon it a few leaves of the *shell lac* softened above the fire; keep alternately heating and adding more *shell lac*, until you obtain a mass of three or four pounds of liquefied *shell lac* upon the end of your stick. Knead this upon a wetted board, with three ounces of levigated cinnabar, and form it into cylindrical pieces; and to give them a polish, rub them while hot with a cotton cloth.

For japanning, take a lump of *shell lac*, prepared in the manner of sealing-wax, with whatever colour you please, fix it upon the end of a stick, heat the polished wood over a charcoal fire, and rub it over with the half-melted lac, and polish by rubbing it even with a piece of folded plantain leaf held in the hand; heating the lacquer, and adding more lac as occasion requires. Their figures are formed by lac, charged with various colours in the same manner. In ornamenting their images and religious houses, &c. they make use of very thin beaten lead, which they cover with various varnishes, made of lac charged with colours. The preparation of them is kept a secret. The leaf of lead is laid upon a smooth iron heated by fire below, while they spread the varnish upon it.

For grindstones, take of river sand three parts, of seed lac washed one part, mix them over the fire in a pot, and

form the mass into the shape of a grindstone, having a square hole in the centre, fix it on an axis with liquefied lac, heat the stone moderately, and by turning the axis it may be easily formed into an exact orbicular shape. Polishing grindstones are made only of such sand as will pass easily through fine muslin, in the proportion of two parts of sand to one of lac. The sand is composed of small angular crystalline particles, tinged red with iron, two parts to one of black magnetic sand. The stone-cutters, instead of sand, use the powder of a very hard granate, called Corunde. These grindstones cut very fast: when they want to increase their power, they throw sand upon them, or let them occasionally touch the edge of a vitrified brick. The same composition is formed upon sticks; for cutting stones, shells, &c. by the hand.

For painting, take one gallon of the red liquid from the first working for shell lac, strain it through a cloth, and let it boil for a short time, then add half an ounce of fossil alkali; boil an hour more, and add three ounces of powdered load (bark of a tree), boil a short time, let it stand all night, and strain next day. Evaporate three quarts of milk, without cream, to two quarts, upon a slow fire, curdle it with some milk, and let it stand for a day or two, then mix it with the red liquid above-mentioned; strain them through a cloth, add to the mixture 1½ oz. of alum, and the juice of eight or ten lemons; mix the whole, and throw it into a cloth-bag strainer. The blood of the insect forms a coagulum with the caseous part of the milk, and remains in the bag, while a limpid acid water drains from it. The coagulum is dried in the shade, and is used as a red colour in painting and colouring.

For dyeing, take one gallon of the red liquid prepared as before without milk, to which add three ounces of alum. Boil three or four ounces of tamarinds in a gallon of water, and strain the liquor. Mix equal parts of the red liquid and tamarind water over a brisk fire. In this mixture dip and wring the silk alternately, until it has received a proper quantity of the dye. To increase the colour, increase the proportion of the red liquid, and let the silk boil a few minutes in the mixture. To make the silk hold the colour, they boil a handful of the bark called load in water; strain the decoction, and add cold water to it; dip the dried silk into this liquor several times, and then dry it. Cotton cloths are dyed in this manner; but the dye is not so lasting as in silk. The lac colour is preserved by the natives upon flakes of cotton dipped repeatedly into a strong solution of the lac insect in water, and then dried. The Hindoos, as Mr. Charles Wilkins informed Mr. Hatchett, dissolve *shell lac* in water, by the mere addition of a little borax; and the solution, being then mixed with ivory-black, or lamp-black, is employed by them as an ink, which, when dry, is not easily acted upon by damp or water. Mr. Hatchett found this fact to be exactly as it was stated by Mr. Wilkins.

Besides the lac above-mentioned, there is another sort which is white or yellowish, brought from Madagascar, very much resembling the pe-la of the Chinese, which has been lately examined by Dr. Pearson. See *LACCIC Acid*.

Mr. Hatchett (*Phil. Trans.* for 1804, part ii.), has detailed a number of experiments for the analysis of the three common species of lac, with a view of ascertaining its constituent parts and discriminating properties.

Lac, though long known in Europe, has not much attracted the attention of chemists. The first person who subjected it to a regular examination was the younger Geoffroy, the result of which is published in the *Mem. de l'Acad. de Paris* for 1714. He concluded that this substance is not, as some have supposed, a gum or resin, which

has exuded from vegetables simply punctured by insects. Geoffroy and Lemery obtained from lac, by distillation, some acid liquor, and a butyraceous substance; and Geoffroy observes, that when stick-lac was thus treated, some ammonia was also obtained, but not when seed-lac was employed. Geoffroy considered lac as a kind of wax, very distinct from the nature of gum or resin. Since his time it has been little examined, and therefore chemists have entertained various opinions concerning it. Chaptal, adopting Geoffroy's opinion, calls it a kind of wax; but Gren and Fourcroy regard it as a true resin.

Mr. Hatchett found that when water is poured on stick lac, reduced to powder, it immediately began to be tinged with red, and by heat, a deep-coloured crimson solution was formed. Repeated operations of this kind reduce stick-lac to a yellowish-brown substance, and the water no longer receives any colour. The portion separated from the lac has, on an average, amounted to 10 *per cent.*; but as it cannot be completely separated, considerable variations must be expected in different samples.

Fine seed-lac does not afford more than $2\frac{1}{2}$ or 3 *per cent.* of the colouring substance; and shell-lac, when treated in the same manner, *i. e.* merely with water, did not yield more than $\frac{1}{2}$ *per cent.* Alcohol dissolves a considerable portion of each of the different kinds of lac; and when heat is not employed, the dissolved part is resin, combined with some of the colouring matter; but if the lac is digested with heated alcohol, the solution is more or less turbid, and it is difficult to obtain it in a state of purity and transparency, either by repose or filtration. The solution obtained by digesting stick-lac in alcohol, without heat, is of a dark brownish-red colour; and the insoluble part subsides, retaining the greater part of the colouring matter, most easily soluble in water. The proportion of resin thus dissolved, when stick-lac is treated with alcohol, amounted to 67 or 68 *per cent.* The seed-lac used by Mr. Hatchett was very pure, and yielded to alcohol about 88 *per cent.* of resin, containing little of the colouring matter. Shell-lac, in small fragments, by simple digestion with alcohol, afforded in the first instance nearly 81 *per cent.*; but part of the resin required subsequent operations to separate it, so that the total quantity of resin might be estimated at 91 *per cent.* Sulphuric ether does not seem to act so powerfully upon the varieties of lac as alcohol; and, therefore, ether is not the best menstruum for lac. Concentric sulphuric acid acts first on the colouring matter of lac; and after a short digestion in a sand-bath, the whole is converted into a reddish-brown thick liquor, which soon becomes black; and the chief part of the lac is separated in an insoluble state, resembling coal. During the solution of lac in sulphuric acid, a considerable quantity of sulphureous acid gas is evolved. When lac is digested with nitric acid, nitrous gas is at first produced; the lac swells much, and is converted into a deep yellow opaque brittle substance, which, by a sufficiency of nitric acid, and a continuance of the digestion for about 48 hours, is dissolved.

This yellow nitric solution is converted by evaporation into a deep yellow substance, which burns like resin, but is soluble in boiling water. Muriatic acid dissolves the colouring matter and gluten of lac with a feeble action, unless the resin has been previously separated. Acetous acid much resembles the muriatic in its effects. Stick-lac, seed lac, and shell-lac are partially dissolved by acetic acid; and the dissolved part consists of the colouring extract of resin, and of gluten; the wax being the only ingredient which is insoluble in this menstruum. A saturated solution of boracic acid in water dissolves the colouring extract; but

the lac is little, if at all, acted upon by this acid. Subborate of soda or borax has a powerful effect on lac, so as to render it soluble in water; and it is concluded from these facts, that the excess of soda in borax is the active substance, which conclusion is corroborated by experiments made with the alkalis. In order to render lac, especially shell-lac, soluble in water, about one-fifth of borax is necessary. The best proportion of water to that of lac is 18 or 20 to 1; so that 20 grains of borax, and 4 oz. of water, are, upon an average, requisite to dissolve 100 grains of shell-lac. The general properties of the solution shew, that it is a saponaceous compound, which, being used as a varnish, or vehicle for colours, becomes (when dry) difficultly soluble in water. The lixivium of pure soda, and of carbonate of soda, completely dissolve the several kinds of lac; and the solutions resemble those formed by means of borax, excepting that they are deeper coloured. Lixivium of pure or caustic potash speedily dissolves the varieties of lac, and forms saponaceous solutions, similar to that with borax, exclusive of the colour, which more approaches to purple. Lixivium of carbonate of potash extracts a great part of the colouring matter, but less completely dissolves the entire substance of lac than pure potash. Pure ammonia, and carbonate of ammonia, readily act upon the colouring matter of lac, but do not completely dissolve the entire substance.

From a variety of other experiments, as well as those, the results of which we have given, but which we cannot recite, it appears that the different kinds of lac consist of four substances, namely, extract, resin, gluten, and wax. The extract, when dry, is of a deep red colour, approaching to purplish-crimson; emitting smoke when laid on a red-hot iron, with a smell like that of burned animal matter, and leaving a bulky porous coal; partially soluble in water, hot or cold; more slowly in alcohol, and with a less beautiful colour; insoluble in sulphuric ether; soluble in sulphuric, nitric, and acetic acid; partially in muriatic acid; not very readily in acetous acid; almost perfectly soluble in the lixivium of potash, soda, and ammonia, with a beautiful deep purple colour. When pure alumine is put into the aqueous solution, it does not immediately produce any effect, but with the addition of a few drops of muriatic acid, the colouring matter speedily combines with the alumine, and a beautiful lake is formed. A fine crimson precipitate is also produced by muriate of tin, when added to the aqueous solution: a similar coloured precipitate is also formed by the addition of solution of singlafs. These properties of the colouring substance of lac, especially its partial solubility in water and in alcohol, and its insolubility in ether, together with the precipitate formed by alumine and muriate of tin, indicate that this substance is vegetable extract, perhaps slightly animalized by the coccus.

The resin of lac is of a brownish-yellow colour, emitting on a red-hot iron much smoke, with a peculiar sweet odour, and leaving a spongy coal; completely soluble in alcohol, ether, acetic acid, nitric acid, and the lixivium of potash and soda; precipitated by water from alcohol, ether, acetic acid, and partially from nitric acid; and possessing the other general characters of a true resin.

The gluten is obtainable in two ways; if the pieces of lac, after digestion in alcohol, be digested with dilute acetic, or muriatic acid, most of the gluten is dissolved, and may be precipitated by alkalis, added in due proportion; but is redissolved by an excess of them, and then is separable by acids. It much resembles the gluten of wheat.

The wax of lac is found floating like oil on the surface of a solution of lac, after long and repeated digestion in boiling nitric acid, and may be collected when cold; or it may

be more easily obtained in a pure state, by digesting the residue left by alcohol in boiling nitric acid. The wax, thus obtained, when pure, is pale yellowish-white, and (unlike bees' wax) is devoid of tenacity, and extremely brittle: it melts at a much lower temperature than that of boiling water, and burns with a bright flame, and an odour resembling that of spermaceti. It is insoluble in water and cold alcohol; but the latter, when boiled, partially dissolves it, and upon cooling, deposits the greater part; soluble in heated sulphuric ether, but upon cooling, nearly the whole is deposited. Lixivium of potash, boiled with the wax, forms a milky solution; but most of the wax floats on the surface in the state of white flocculi, and appears to be converted into a kind of soap of difficult solubility; it is no longer inflammable; and, with water, forms a turbid solution, from which, as well as from the solution in potash, the wax may be precipitated by acids. Ammonia, when heated, dissolves a small portion of the wax, and forms a solution similar to the former; nitric and muriatic acids do not act upon the wax. When the properties of this substance are compared with those of bees' wax, a difference will be perceived; and on the contrary, the most striking analogy is evident between the wax of lac and the myrtle wax which is obtained from the *Myrica cerifera*. The properties of myrtle wax, described by Dr. Bostock in Nicholson's Journal for March, 1803, coincide so perfectly with those of the wax of lac, that Mr. Hatchett is led to consider them as almost, if not altogether, the same substance.

Our author, from his analysis of the three different species of lac infers, that the substances that compose them bear the following proportions: 100 parts of stick-lac gave 68 of resin, 10 of colouring extract, 6 of wax, 5.5 of gluten, and 6.5 of extraneous substances: 100 parts of seed-lac gave 88.5 of resin, 2.5 of colouring extract, 4.5 of wax, and 2 of gluten: 100 parts of shell-lac gave 90.9 of resin, 0.5 of colouring extract, four of wax, and 2.8 of gluten.

We have already specified several uses to which lac is applied in India, and it is no less important, in a variety of respects in Europe. A solution of lac in water may be advantageously employed as a sort of varnish, which is equal in durability, and other qualities, to those prepared with alcohol; and, of course, much cheaper. It will be found, likewise, of great use as a vehicle for colours; for, when dry, it is not easily affected by damp, or even by water. Mr. Hatchett says, that with a solution of this kind he has mixed various colours, such as vermilion, fine lake, indigo, Prussian blue, sap-green, and gamboge; and it is remarkable, that although the two last are of a gummy nature, and the others had been previously mixed with gum (being cakes of the patent water-colour), yet, when dried upon paper, they could not be removed with a moistened sponge, until the surface of the paper itself was rubbed off. In many arts and manufactures, therefore, the solutions of lac may be found of great utility; for, like mucilage, they may be diluted with water, and yet, when dry, are little, if at all, affected by it.

The colour given by lac is less beautiful, but more durable than that given by cochineal. To render the colouring matter of the lac diffusible in water, so as to be applied to the stuffs to be dyed, Mr. Hællot directs the following process:—Let some powdered gum-lac be digested for two hours in a decoction of comfrey-root, by which a fine crimson colour is given to the water, and the gum is rendered pale or straw-coloured. To this tincture, poured off clear, let a solution of alum be added; and when the colouring matter has subsided, let it be separated from the clear liquor, and dried. It will weigh about one-fifth

of the quantity of lac employed. This dried fecula is to be dissolved or diffused in warm water, and some solution of tin is to be added to it, by which it acquires a vivid scarlet colour. This liquor is to be added to a solution of tartar in boiling water; and thus the dye is prepared.

The method of obtaining the fine red lac used by painters from this substance, is by the following simple process:—Boil the stick-lac in water, filter the decoction, and evaporate the clear liquor to a dryness over a gentle fire. The occasion of this easy separation is, that the beautiful red colour, here separated, adheres only slightly to the outsidings of the sticks, broken off the trees along with the gum-lac, and readily communicates itself to boiling water. Some of this sticking matter also adhering to the gum itself, it is proper to boil the whole together; for the gum does not at all prejudice the colour, nor dissolve in boiling water: so that after this operation the gum is as fit for making sealing-wax as before, and for all other uses which do not require its colour. See LAKE.

A tincture of gum-lac may thus be prepared:—Take two ounces of gum-lac, reduce it to a fine powder, and make it into a stiff paste with oil of tartar *per deliquium*; set this in an open glass to dry by a gentle heat, then remove it to the open air, that it may relent and grow soft; then dry it again, and repeat this two or three times, at the end of which the hard body of this resin will be found resolved into a purple colour. This may yet again be dried, and when dried must be reduced to powder, which powder will afford a fine strong tincture to spirit of wine, being boiled in it in a tall glass in a sand-heat for two or three hours. And by this process strong tinctures may be made from myrrh, amber, gum, juniper, &c. which will yield no tincture of strength to spirit of wine alone, if treated in the usual way.

A spirituous tincture of stick-lac was formerly sometimes given as a mild restraining and corroborant in female weaknesses, and in rheumatic and scorbutic disorders. But the principal medicinal use of this concrete was as a topical corroborant and antiseptic, in laxities and scorbutic bleedings, and ulcerations of the gums. Some employed for this purpose a tincture of the lac in alum water; others a tincture made in vinous spirits, impregnated with the pungent antiscorbutics. The college of Edinburgh directed an ounce of the powdered lac, with half an ounce of powdered myrrh, to be digested in a sand-heat, for six days, in a pint and a half of spirit of scurvy grass.

The gum-lac has been lately used as an electric, instead of glass, for electrical machines. See LACQUER, LAKE, and VARNISH.

LAC, or LACCA, *Ammoniaca*, in the *Materia Medica*. See GUM AMMONIAC.

LAC, or LACCA, *Artificial*, or LAQUE, is also a name given to a coloured substance, drawn from several flowers; as the yellow from the flower of the juniper, the red from the poppy, and the blue from the iris or violet.

The tinctures of these flowers are extracted by digesting them several times in aqua vitæ, or by boiling them over a slow fire in a lixivium of pot-ashes and alum.

An artificial lacca is also made of Brazil wood, boiled in a lixivium of the branches of the vine, adding a little cochineal, turmeric, calcined alum, and arsenic, incorporated with the bones of the cuttle-fish pulverized, and made up into little cakes, and dried.

If it be to be very red, they add the juice of lemon to it; to make it brown, they add oil of tartar.

Dove-coloured, or columbine lacca, is made with Brazil of Fernambuc, steeped in distilled vinegar for the space of a

month, and mixed with alum incorporated in cuttle-fish bone. For other processes, see LAKE and Madder.

LAC, *Acid of*. See LACCIC *Acid*.

LAC, or *Gum Lac*. See CROTON.

Lace

LACE, in the *Manufactures*, is formed of thread, cotton, or silk, woven into a net, the meshes of which are varied in their figure, according to the design of the pattern, as octagons, hexagons, &c. &c. The lace is also ornamented by a thread, much thicker than the thread forming the net, which is woven in among the meshes, in the figure of flowers, and other fantastic curves; upon the beauty and elegance of which, the value of the lace depends. This thick thread is called the *gimp*.

Lace is made upon a pillow or cushion, upon which a piece of stiff parchment is stretched, having a number of holes pricked through it, to form a pattern of the intended lace. Through these holes, pins are stuck into the pillow; and the threads, wound upon small bobbins, are woven around the pins, and twisted round each other in various ways, to form the required pattern. This process is extremely tedious, particularly for the wide laces, with complicated patterns; and though it is extremely expensive to

the consumer, the people (chiefly in Bedford and Buckinghamshire) who manufacture it can only obtain sufficient to support a wretched existence, by the most incessant exertion. Of late years, the manufacturers of Nottingham have directed their ingenuity to imitate this species of lace by machinery, in which they have succeeded most perfectly; but still it is only an imitation, the knot or loop of the meshes being essentially different. In the pillow lace, the net or meshes may be described, by supposing a number of ropes, each formed of two or more threads twisted round each other: these are extended parallel; but at every two or three spiral turns of these ropes, the strands or threads composing one rope are twisted around with those of its neighbour, and then return to be twisted with its own: and this reciprocally of the whole number forms a netting; the figure of the meshes depending upon the number of turns which are made, before the twist is changed from one rope to the next. To form a lace of this description, it is essential that

the ends of each thread be detached, and capable of being twilted over the adjacent threads. This is easily done by the hand upon the pillow, by twifting the bobbins round each other; but has many difficulties which prevent its performance by machinery.

The Nottingham lace is only a modification of the stitch or loop of which stockings are made; all the meshes being formed by a continuance of one thread, which is, by the machine, formed into loops a whole course (that is, length of the intended piece of lace) at once, by pressing it down alternately over and under between a number of parallel needles; a second course is then made of similar loops on the same needles, and the loops of the first are drawn through those of the second, in such a manner as to form meshes by retaining the first loops; the second are then retained by a third course, and this by a fourth, and so on. The machine is very nearly like a common stocking-frame, but provided with an additional apparatus, which can be readily applied. It consists of a frame, containing a number of needles, which we will call points; these are introduced between the fixed needles of the stocking-frame, and a certain number (one half, for instance) of the loops in the thread are taken off the fixed needles upon these points, which are moved endways, the space of two, three, or more fixed needles, and put down upon them again. Another set of loops is now taken upon the points, and moved in the opposite direction; by this means, crossing the loops over each other, and forming meshes, the figure of which will depend upon the number of needles it is thus carried over. But as this admits of no great variety of patterns, another machine has been invented, which is much more extended in its applications. Like the former, it has the parts of the stocking-frame, but differently made. The thread is, in this, rolled upon a cylinder, in the same manner as a weaver's beam; as many threads being wound round it as there are needles in the frame. These threads pass through eyes in the ends of small points, called guides, which are opposite the needles; and these guides are fixed on two bars, each of which has half the guides fastened in it, that is, one-guide is fast in one bar, and the next in the other, and so on alternately of the whole. Each of the guides presents a thread to its needle, and are all at once moved by the hand to twilt

the threads two or three times round the needles which are opposite them: the loop is now made in a manner similar to the other frame. The next time, the alternate guides are shifted endways, so as to apply themselves to other needles than those they were opposite before. This crosses the thread, so as to make a net: but the quantity which is shifted endways is altered every time, by means of the machinery, so as to move a certain number of needles; which number is altered every time, to produce the pattern. All the parts of this machine, except the guides, are moved by means of treadles, instead of using the hands, as in the common stocking-frame. The net produced by these frames is woven in bands of the width of the intended lace, leaving a wider mesh than the others, through which the division is to be made to separate the lace into narrow strips. Before cutting up in this manner, the lace is spread in a frame, and a common needle with a thick thread is worked in the meshes, to imitate the gimp, according to the pattern for which the lace is intended.

The lace trade of Nottingham has been carried to a very great extent, but is at present in a state of stagnation, being chiefly dependent on foreign trade, as it has never been in such great repute with the British ladies.

Lace is also made of *gold* and *silver thread* (which see), much in the same manner as the bone or blond lace above described. The importation of gold and silver lace is prohibited. Great quantities of the finest blond laces have been imported from Flanders. By 3 Geo. III. c. 21. and 5 Geo. III. c. 48. if any person shall import any ribbands, laces, or girdles, not made in Great Britain, whether the same shall be wrought of silk alone, or mixed with other materials, the same shall be forfeited, and may be seized by any officer of the customs, in whatever importers', venders', or retailers' hands they may be found; and the importer, and every person assisting therein, and the venders and retailers in whose custody they shall be found, or who shall sell or expose the same to sale, or conceal with intent to prevent the forfeiture, shall forfeit respectively 200*l.* with costs; half to the king, and half to the officer who shall inform and prosecute.

LACE is also used for a kind of chord made of silk or cotton, chiefly used in lacing women's stays.

Lacquer

LACQUER, or LACKER, is a varnish applied upon tin, brass, and other metals, to preserve them from tarnishing, and to improve their colour. The basis of lacquers is a solution of the resinous substance called seed-lac, or rather shell-lac, in spirit of wine. This spirit ought to be very much dephlegmated in order to dissolve much of the lac. For this purpose, some authors direct dry pot-ash to be thrown into the spirit. This alkali attracts the water, with which it forms a liquid that subsides distinctly from the spirit at the bottom of the vessel. From this liquid the spirit may be separated by decantation. By this method the spirit is much dephlegmated: but at the same time it becomes impregnated with part of the alkali, which depraves its colour, and communicates a property to the lacquer of imbibing moisture from the air. These inconveniences may be prevented by distilling the spirit; or, if the artist has not an opportunity of performing that process, he may cleanse the spirit in a great measure from the alkali, by adding to it some calcined alum, the acid of which uniting with the alkali remaining in the spirit, forms with it a vitriolated tartar, which, not being soluble in spirit of wine, falls to the bottom together with the earth of the decomposed alum. To a pint of the dephlegmated and purified spirit, about three ounces of powdered shell-lac are to be added; and the mixture to be digested during some days with a moderate heat. The liquor ought then to be poured off, strained, and cleared by settling. This clear liquor is now fit to receive the required colour, from certain resinous colouring substances, the principal of which are gamboge and anotto, the former of which gives a yellow, and the latter an orange colour. In order to give a golden colour, two parts of gamboge are added to one of anotto; but these colouring substances may be separately dissolved in the tincture of lac, and the colour required may be adjusted by mixing the two solutions in different proportions. When silver-leaf, or tin, are to be lacquered, a larger quantity of the colouring materials is requisite than when the lacquer is intended to be laid on brass.

There are sundry other materials, from a due mixture of which a like colour may be produced, as turmeric, saffron, dragon's blood, &c. See *Gold Coloured VARNISH*, and *Japanner's GILDING*.

Instead of shell-lac, used in the composition of varnishes for lacquering, resin or turpentine is substituted for the coarser uses. The following composition for brass-work, designed to resemble gilding, has been much recommended:

take of turmeric ground, as it may be had at the dry-salters, one ounce, and of saffron and Spanish anotto each two drams: put them into a bottle with a pint of highly rectified spirit of wine, and place the bottle in a moderate heat, occasionally shaking it, for several days; then strain off the yellow tincture thus obtained, through a coarse linen cloth, and putting it back into the bottle, add three ounces of good seed-lac grossly powdered; place the bottle again in a moderate heat and shake it, till the seed-lac be dissolved. The lacquer strained as before will be fit for use, and must be kept in a bottle carefully stoppered. By increasing or diminishing the proportion of anotto, the lacquer will be rendered warmer and redder, or cooler and nearer a true yellow. A cheaper composition little inferior to the former, may be formed of one ounce of turmeric root ground, half a dram of the best dragon's blood, and a pint of spirit of wine, managed as the former.

The varnish for tin may be made of one ounce of turmeric-root, two drams of dragon's blood, and one pint of spirit of wine, prepared in the same manner with the other. The dragon's blood may be increased or diminished, as the red or yellow is to be the most prevalent; and for a coarser lacquer the quantity of shell-lac may be lessened, and the deficiency supplied by the same proportion of resin. The lacquer for locks, nails, &c. where little or no colour is desired, may be either shell-lac varnish alone, or with a little dragon's blood; or a compound varnish of equal parts of shell-lac and resin, with or without the dragon's blood. The manner of laying on the lacquer is as follows: the pieces to be lacquered must first be made thoroughly clean; and if they be new founded, aquafortis must be used for this purpose. When they are afterwards heated by a small charcoal fire, the lacquer is laid on with a proper brush, like other varnishes, and the pieces restored to the heat. After the lacquer is thoroughly dry and firm, the same operation must be renewed for four or five times, or till the work appears of the required colour and brightness.

The lacquering of leather, improperly called gilding, is performed by means of leaf-silver, coloured by a yellow varnish. (See *Japanner's GILDING*.) For this purpose calf or goat-skins are procured in a dry state, after the common dressing and tanning. They are softened by being immersed and stirred about for some hours in a tub of water; and afterwards beaten against a flat stone and smoothed, by spreading them on the stone and rubbing

them over with an iron instrument: the skins, thus prepared, are joined together in pieces of the dimensions required; and then sized on the grain of the leather with a kind of soft glue, or stiff size, that answers to the gold-size used in other kinds of gilding or silvering, prepared from parchment or glover's cuttings. The workman next proceeds to cover the whole surface of the sized skin, before it be quite dry, with leaf silver, and with a fox's tail, made into the form of a ball at the end, settles the leaves, by pressing and striking them; and closes this operation with gently rubbing the whole surface with the tail. When the skins are silvered, they are hung to dry first on cords, and the drying is completed by putting them over a board joined together, with the silvered side next the boards, where they must be kept stretched out by means of some nails. They are then burnished with a flint burnisher, which operation is performed by spreading the skin even on a smooth stone, and sliding the burnisher backwards and forwards over every part of the skin, with a considerable degree of pressure. In some manufactures the burnishing is performed, by passing the silvered skins betwixt two cylindrical rollers of steel, with polished faces. The skins are now prepared for receiving the yellow lacquer or varnish, which gives the appearance of gilding. Different artists have different recipes for compounding this lacquer. The following is said to be equal to any hitherto used: take of fine white resin, 4. pounds; the same quantity of common resin; of gum sandarac, 2½ pounds; and of aloes, two pounds: bruise and mix them; and put them into an earthen pot over a good fire of charcoal, or over any other fire which has no flame: when all the ingredients are perfectly melted and mixed, add gradually to them seven pints of linseed oil, and stir the whole well together with a spatula: let the whole boil, stirring all the time, to prevent a kind of sediment, that will form, from sticking to the bottom of the vessel. When the varnish is almost sufficiently boiled, which will generally require seven or eight hours, add gradually half an ounce of litharge, or half an ounce of red lead; and when this is dissolved, pass the varnish through a linen cloth, or flannel bag. A pint of oil, and a corresponding proportion of fine resin and aloes, have

produced a very good varnish in an hour and a half. This lacquer or varnish is laid on the silvered leather in the open air; and is best done in summer, when it is hot and dry. For this purpose, the skins are stretched and fastened with nails to the boards, on which the drying was finished, with the silvered side outwards. And when these boards are properly disposed on treffels, the workman generally spreads some white of eggs over each skin; and when this is dry, the varnish, which is nearly of the consistence of a thick syrup, is repeatedly spread with the four fingers of one hand, moved so that each finger paints a kind of S with the varnish, from one end of the skin to the other: and it is then diffused evenly over every part with the flat of the hand: after this it is to be immediately beaten by strokes of the palms of the hands, and principally where the varnish is observed to lie thickest. When this coat of varnish is sufficiently dry, which may be known by the fingers making no impression upon it, another coat is laid on in the same manner. When this coat is dry, the varnishing for producing the appearance of gilding is completed; and if it has been well performed, the leather will have a very fine gold colour, with a considerable degree of polish or brightness. When there is an intention to have one part of the leather silver, and the other gold, a pattern is formed on the surface, by printing, calking or stamping, a design on the surface after the silvering. The skin is then to be varnished, as if the whole were intended to be gold; but after the last coat, instead of drying the varnish, it is to be immediately taken off that part, which is intended to be silver, according to the design printed or calked upon it, by a knife; with which the workman scrapes off all that he can without injuring the silver, and afterwards by a linen cloth, with which all that remains is to be wiped or rubbed off. The skins thus silvered and varnished, are made the ground of various designs for embossed work and painting. The embossed work or relief is raised by means of printing with a rolling press, such as is used for copper-plates; but the design is here to be engraved on wood. The painting may be of any kind; but oil is principally used, as being durable and more easily performed. *Dossie's Handmaid to the Arts*, vol. i. p. 454, &c.

Lake

LAKE, or **LAQUE**, a preparation of different substances into a kind of magiftery for the use of painters, dyers, &c. One of the finest and first invented of which was that of *gum*

lacca or *lacque*; from which all the rest, as made by the same process, are called by the common name *lacques*. See **LAC** or **LACCA**.

We may observe more generally, that all vegetable colours, which are soluble in water, are found to have a certain degree of affinity for some earths and metallic oxyds. These combinations are called lakes. Thus, if a solution of alum is added to an infusion of madder, a mutual decomposition takes place, and part of the alumine falls down intimately united with the colouring matter of the madder: the separation is much assisted by the alkali. They are chiefly of two colours only, red and yellow: the red owing their colour to madder, Brasil wood, or cochineal; and the yellow to the different yellow infusions used in dyeing. Both are generally used for water colours, and in oil painting as transparent colours. These pigments are almost invariably composed either of alum, or sometimes the solution of tin, and some other watery solution of a colouring matter.

Of the red lakes, that made with cochineal is the most beautiful, and of the greatest value. It is called *carmine*, from its being applied to imitate the colour of the flesh. For the method of preparing it, see COCHINEAL. See also CARMINE.

On the receipt for making carmine, introduced under the article COCHINEAL, a correspondent has made the following observation.

The carbonat of soda and alum, added in the first instance, would be mutually decomposed, and the alumine, with the colouring matter, would be precipitated with the dregs, which are afterwards separated from the clear liquor; so that when the white of egg came to be added, the earth of the alum and a portion of the colouring matter, said to be carried down by the albumen, cannot be present. Should the process here given have any analogy to that which is practised, it would appear that the solution of cochineal in water has the white of egg added to it, in the first instance, if it is at all necessary, for the purpose of clearing the coloured solution, a property for which that substance is remarkable. That after the liquid becomes clear, and is separated from the dregs, the carbonat of soda and alum are added, when a precipitate, consisting of the alumine united with the finer parts of the colouring matter, may be expected. The remaining colouring matter, which is of less beauty, is then used for the red lake.

Instead of using cochineal for making carmine, a much clearer colour may be extracted from the refuse of scarlet cloth. The bits of cloth are boiled in a solution of potash, which extracts the colour, and holds it in solution. If to this a certain portion of alum be added, the colouring matter will be precipitated with the alumine, of a greater or less intensity, proportionate to the quantity of this earthy basis. In Dossie's Handmaid to the Arts, we are told that the best of the lakes commonly sold is made from the colour extracted from scarlet rags, and deposited on the cuttle-bone; and that it may be prepared in the following manner: dissolve a pound of the best pearl ashes in two quarts of water, and filter the liquor through paper; add to this solution two more quarts of water, and a pound of clean scarlet shreds, and boil them in a pewter boiler, till the shreds have lost their scarlet colour; take out the shreds and press them, and put the coloured water yielded by them to the other: in the same solution boil another pound of the shreds, proceeding in the same manner; and likewise a third and fourth pound. Whilst this is doing, dissolve a pound and a half of cuttle-fish bone in a pound of strong aqua-fortis, in a glass receiver, adding more of the bone, if it appear to produce any ebullition in the aqua-fortis; and pour this strained solution gradually into the other; but if any ebullition be occasioned, more of the cuttle-fish bone must be dissolved as before, and added, till no ebullition appears in the mixture. The crimson sediment deposited by the liquor thus prepared

is the lake: pour off the water, and stir the lake in two gallons of hard spring water, and mix the sediment in two gallons of fresh water; let this method be repeated four or five times. If no hard water can be procured, or the lake appears too purple, half an ounce of alum should be added to each quantity of water before it be used. Having thus sufficiently freed the lake from the salts, drain off the water through a filter, covered with a worn linen cloth. When it has been drained to a proper dryness, let it be dropped through a proper funnel on clean boards, and the drops will become small cones or pyramids, in which form the lake must be suffered to dry, and the preparation is completed.

Lakes are also made from madder and Brasil wood. The former is much more permanent than the latter, but does not possess the same beauty of tint. In order to make these lakes, strong infusions of these substances are first obtained. The Brasil wood infusion is best made by boiling the chips in pure water, and filtering the solution. (See BRASIL Wood.) The infusion of madder (see Madder) is best made in cold water, by which the purest part of the colour is only dissolved. To each of these solutions are added a clear solution of alum, and then as much of an alkali as will precipitate so much of the alumine as will make the colour of the precipitate of proper intensity. A small quantity of muriate of tin increases the brilliancy of these lakes.

A beautiful lake, it is said (*ubi infra*), may be prepared from Brasil wood, by boiling three pounds of it, for an hour, in a solution of three pounds of common salt, in three gallons of water; and filtering the hot fluid through paper, add to this a solution of five pounds of alum in three gallons of water. Dissolve three pounds of the best pearl ashes in a gallon and a half of water, and purify it by filtering; put this gradually to the other, till the whole of the colour appears to be precipitated, and the fluid be left clear and colourless. But if any appearance of purple be seen, add a fresh quantity of the solution of alum by degrees, till a scarlet hue be produced. Then pursue the directions given in the first process with regard to the sediment. If half a pound of seed-lac be added to the solution of pearl ashes, and dissolved in it before its purification by the filter, and two pounds of the wood, and a proportional quantity of the common salt and water be used in the coloured solution, lake will be produced that will stand well in oil or water, but it is not so transparent in oil as without the seed-lac. The lake with Brasil wood may be also made by adding half an ounce of anotto to each pound of the wood; but the anotto must be dissolved in the solution of pearl ashes. There is a kind of beautiful lake brought from China; but as it does not mix well with either water or oil, though it dissolves entirely in spirit of wine, it is not of any use in our kinds of painting. This has been erroneously called *safflower*. Handmaid to the Arts, vol. i. p. 61, &c.

In making yellow lakes, the coloured infusions must be such as to make the most permanent dye. (See DYEING.) The precipitation of the colour is performed precisely in the same way, and by the same substances, as the red lakes. A very excellent yellow lake may be made from the infusion of *quercitron bark*. That from *turmeric* is very beautiful, but is not permanent. The process for the making of this is as follows: take a pound of turmeric-root in fine powder, three pints of water, and an ounce of salt of tartar; put all into an earthen glazed vessel, and let them boil together over a clear, gentle fire, till the water appears highly impregnated with the root, and will stain a paper to a beautiful yellow. Filter the liquor, and gradually add to it a strong solution of rock-alum in water, till the yellow matter is all curdled together, and precipitated; after this pour the whole into a

filtrate of paper, and the water will run off and leave the yellow matter behind. It is to be washed many times with fresh water, till the water comes off insipid, and then is obtained the beautiful yellow, called *laque of turmeric*, and used in painting.

In this manner may a laque be made of any of the tinging substances that are of a somewhat strong texture, as madder, logwood, &c.; but it will not succeed in the more tender species, as the flowers of roses, violets, &c. as it destroys the nice arrangement of parts in those subjects, on which the colour depends.

A yellow lake for painting is to be made from broom-flower in the following manner: make a ley of pot-ashes and lime reasonably strong; in this boil, at a gentle fire, fresh broom-flowers till they are white, the ley having extracted all their colour; then take out the flowers, and put the ley to boil in earthen vessels over the fire; add as much alum as the liquor will dissolve; then empty this ley into a vessel of clear water, and it will give a yellow colour at the bottom. Let all settle, and decant off the clear liquor. Wash this powder, which is found at the bottom, with more water, till all the salts of the ley are washed off; then

separate the yellow matter, and dry it in the shade. It proves a very valuable yellow.

All the lake colours are changed by acids and alkalies. An acid renders the red lake more scarlet, and the yellow paler; while an alkali gives a purple tint to the red, and an orange or brown tint to the yellow. Artists sometimes take advantage of this property to change their colours. The acid used for this purpose should be the muriatic diluted, and the alkali aqua ammonia.

LAKE, *Orange*, is the tinging part of anotto precipitated together with the earth of alum. This pigment, which is of a bright orange colour, and fit for varnish painting, where there is no fear of flying, and also for putting under crystal to imitate the vinegar garnet, may be prepared by boiling four ounces of the best anotto and one pound of pearl-ashes half an hour in a gallon of water; and straining the solution through paper. Mix gradually with this a solution of a pound and a half of alum in another gallon of water; desisting, when no ebullition attends the commixture. Treat the sediment in the manner already directed for other kinds of lake, and dry it in square bits or round lozenges. *Handmaid to the Arts*, vol. i. p. 110.

Lambeth

LAMBETH, an extensive parish, seated on the southern bank of the river Thames, in the hundred of Brixton, and county of Surrey, England. It is directly opposite to Westminster, to which city it is connected by a handsome stone bridge across the river. The whole is bounded by Southwark to the east, Newington Butts and Camberwell to the south, and Battersea to the west. The circumference is about 16 miles. In Domesday-book, it is said to contain $20\frac{1}{2}$ plough-lands. At the beginning of the seventeenth century, it appears, by the churchwardens accounts, to have consisted of 1262 acres of arable land, 1026 of pasture, 125 of meadow, 13 of ozier, 27 of garden ground, and 150 of wood, making in the whole 2603; the commons and waste land, supposed to be about 330 acres, not being charged, will increase it to 2933 acres. At present, the whole extent is about 4000 acres; of which about 1390 are occupied by houses and other buildings, wharfs, manufactories, streets, and roads; 415 by pleasure gardens, including those of Vauxhall; 80 by market gardens; 300 by farming gardens; 40 by nurseries; 250 are now inclosing from common; and 30 are to remain common. The parish is divided into six liberties or precincts, respectively called the Bishop's, the Prince's, Vauxhall, Marsh and Wall, Lambeth-Dean, and Stockwell; the whole containing, according to the return to parliament in the year 1800, 5009 houses, and 27,985 inhabitants, of whom 5148 were stated to be employed in various trades and manufactures, and 955 in agriculture. Archbishop Hubert Walter obtained from king John a grant of a weekly market, and a fair of fifteen days, upon condition that the same should not be detrimental to the interests of the city of London. In the archbishop's

MS. library, is a charter from the city, signifying their consent, stipulating only, that the fair should begin on the morrow after the anniversary of St. Peter ad vincula. The market and fair are both discontinued. The earliest historical fact on record relating to Lambeth, is the death of Hardicanute, which happened here in the year 1041, while he was celebrating the marriage feast of a noble Dane. Here also, Harold, who usurped the throne on the death of Edward the Confessor, is said to have placed the crown on his head with his own hands. Henry III. held a solemn Christmas here in the year 1231; and a parliament on September 14, in the year following. A most violent outrage was committed in Lambeth church, on Sunday February 19, 1642-3. The story is variously told by the different parties; but it stands on record as an instance of the fatal effects of civil discord, from the outrages of which no place, however sacred, is exempt.

Of the archbishop's palace, the chief object of note in the parish, it will be proper to state a few particulars. It is situated near the river; and is certainly a very large pile of building, exhibiting the architectural styles of various ages. It appears that this palace was, in a great measure, if not wholly, rebuilt by archbishop Boniface in the year 1262. If any part of this structure now remains, it is the chapel; the architecture of which might induce one to ascribe it to a more early period. Under the chapel is a crypt, the arches of which are built with stone, as is the chapel; the roof of the latter is of wood and flat; the windows were formerly of painted glass, put up by cardinal Morton. In the chapel were interred the remains of archbishop Parker. The great

hall was rebuilt by archbishop Juxton, after the civil wars, at an expence of 10,500*l*. It is 93 feet long by 38 wide; and has a fine carved wooden roof. The guard room, built before the year 1428, has a roof similar to that of the hall. Cardinal Pole is said to have erected the long gallery, which measures 90 feet by 16. In this room are several portraits of archbishops, and other illustrious characters. In the great dining-room, 38 feet by 19, are also portraits of all the archbishops from Laud to the present time; this series is particularly interesting, as, among other things, they shew the gradual change of the clerical dress. Archbishop Tillotson was the first to wear a wig; which however resembled the natural hair, and was worn without powder. A noble library occupies four galleries, over a small quadrangular cloister. The first collection of books was bequeathed by archbishop Bancroft; but these were seized in the civil wars, and though much injured, and some lost, yet the chief stock was restored by archbishop Juxton, after the restoration. Archbishops Sheldon, Tenison, and Secker augmented the library; and the number of books is now supposed to be, at least, 25,000 volumes. In the windows is some fine painted glass. (See Brayley and Herbert's *Illustrations of Lambeth Palace*, 4to. 1806, for various views of this palace, and portraits, &c. from the painted glass). The MS. library contains a large and valuable collection of records and MSS. At the west end of the chapel is a lofty building, called Lollards' tower, built by archbishop Chichele in the years 1434 and 1435. At the top is a small room called the prison, in which it is said the Lollards were confined. The gateway, and the adjoining tower, which are of brick, were built by archbishop Morton about the year 1490. The gardens and park, which contain nearly thirteen acres, are laid out with great taste; they were much improved by the late archbishop, who made a convenient access to the house, for carriages, through the park. It has been said, but erroneously, that Stephen Langton is the first archbishop upon record who resided at Lambeth. Hubert Walter was there in 1198; and many of the public acts of the metropolitan were performed at Lambeth prior to that period.

Contiguous to the palace is the parish church, which was rebuilt between the years 1374 and 1377. The tower, which is of free-stone, still remains; the other parts of the present structure appear to be about the age of Henry VII. The church now consists of a nave, two aisles, and a chancel. Two chapels, called Howard's and Leigh's, were built in 1522; they were incorporated with the church when it was repaired in 1769. Among the numerous sepulchral memorials in this church, those most worthy notice are for the archbishops Tenison, Hutton, and Cornwallis, and a marble slab to the memory of the celebrated antiquary Elias Ashmole.

In this parish are situated the Asylum, instituted in 1758, for the reception of female orphans; and the Westminster Lying-in-Hospital, built in 1765.

About the end of the seventeenth century, a manufacture of plate glass was established at Vauxhall, in this parish, under the patronage of the duke of Buckingham; the principal artist was Rossetti. It was carried on with great success, and the glass was thought to excel that made at Venice. (See *GLASS* and *LOOKING-GLASS*.) The importation of foreign timber, which for many years has formed a considerable and important branch of our commerce, has been a source of wealth to this parish, where are several wharfs for that trade, supplied with stores which are almost incredible. At Vauxhall are some very large distilleries, and several potteries; the manufacture of stone earthenware pots is said to have been first introduced here from Holland. On the site of Cuper's gardens (formerly a place of public entertainment,) are Messrs. Beaufoy's extensive vinegar works. Mr. Pennant, who went over the premises, mentions a vessel full of sweet wine, containing 58,109 gallons, and another full of vinegar, containing 56,799 gallons; besides these enormous vessels there are several others which contain from 32,500 to 16,974 gallons each. In the year 1769, Mrs. Coade established in this parish, near Westminster bridge, a manufacture of artificial stone, which is cast in moulds and burnt. It is intended to answer the purpose of stone, for every species of ornamental architecture, at a much cheaper rate than carving. Where it has been placed in exposed situations it has been found to endure the frost. Messrs. Watts have lately established a manufacture of patent shot in this parish: the principle of making this shot is, to let it fall from a great height into the water, that it may cool and harden in its passage through the air, and thereby better retain its spherical shape. The height of the tower at this manufactory is about 140 feet; the shot falls 123 feet six inches. About the same time Messrs. Bolton, Morgan, and Co. established a manufacture here under the title of the woollen yarn company; every branch of the clothing manufacture, from sorting the wool to making the cloth, was carried on entirely by machinery; but the undertaking was soon given up. About a century ago, there was a place of entertainment called Lambeth Wells, situated in what is now called Lambeth Walk. A riding-school, for the exhibition of feats of horsemanship, was opened in this parish about the year 1768, by Mr. Philip Astley. At first it was an open area; in 1780 it was converted into a covered amphitheatre, and divided into boxes, pit, and gallery. Spring Gardens, Vauxhall, (which is mentioned in the *Spectator* as a place of great resort,) is open during the greater part of the summer, being illuminated with a great number of lamps; the entertainment consists of a concert of music, performed, in fine weather, in the open air; the price of admission, till 1796, was one shilling; it is now three shillings, and open three times each week during the summer months. *Lysons's Environs of London*, vol. i. 4to.

Lamp

LAMP, an instrument used for the combustion of liquid inflammable bodies, for the purpose of producing artificial light.

The most simple lamp consists of a vessel of almost any shape, containing oil or alcohol, with a tube projecting a little above the surface of the liquid, and containing any fibrous substance capable of raising the liquid to the top of the tube, by capillary attraction. The oil, thus raised and diffused through the fibrous substance, is so detached from the main body of the liquid, as to admit of being heated to a temperature sufficient to volatilize the oil, the vapour of which, in a state of combustion, constitutes the flame of the lamp.

In the management of the lamp of the most simple kind, so far as relates to the supply of oil, three things are necessary to be observed. 1. The wick must be of such a substance as best to promote capillary attraction. 2. It should not be twisted too much, in which case its capacity for the oil is too little; nor should it be so loose as to diminish materially its capillary attractive power. This is frequently the case, when the wick has been too long immersed in the oil. 3. With regard to the distance of the flame from the surface of the oil.—If the flame be too near the surface, a lesser quantity of oil will acquire the intense heat necessary to raise it into vapour, since the heat communicates with the fluid. On the contrary, when the flame is too high above the oil, the capillary attraction, which decreases in some ratio of the distance, is insufficient to supply the necessary quantity of oil.

Experience has long ago established, that cotton is the best medium for the transmission of the oil, which is prepared in a particular way for the purpose.

During the slow combustion of oil, as observed in the common lamp, as well as that of tallow in candles, the fatty matter is decomposed, producing a quantity of vapour, which inflames in contact with oxygen; and a cloudy exhalation in the form of smoke, consisting of numerous small particles of carbonaceous matter, which, if collected, constitute the article called lamp-black. Besides the offensive smell and appearance of this substance, there is an evident waste of combustible matter, capable of producing both light and heat.

The evil arising from the smoke and smell of lamps was formerly so great, as to prevent their introduction into domestic use, notwithstanding the strong inducement of convenience and economy.

The public have long been in possession of a complete remedy for this, and several other disadvantages in lamps, by the invention of the Argand lamp. This invention embraces so many improvements upon the common lamp, and has become so general throughout Europe, that it may be justly ranked among the greatest discoveries of the age. As a substitute for the candle, it has the advantage of great economy and convenience, with much greater brilliance; and for the purpose of producing heat, it is an important instrument in the hands of the chemist.

We may with some propriety compare the common lamp and the candle to fire made in the open air, without any forced method of supplying it with oxygen; while the Argand lamp may be compared to a fire in a furnace, in which a rapid supply of oxygen is furnished by the velocity of the ascending current. This, however, is not the only advantage of this valuable invention. It is obvious that if the combustible vapour occupies a considerable area, the oxy-

gen of the atmosphere cannot combine with the vapour in the middle part of the ascending column. The outside, therefore, is the only part which enters into combustion; the middle constituting smoke. This evil is obviated in the Argand lamp, by directing a current of atmospheric air through the flame, which, instead of being raised from a solid wick, is produced from a circular one, which surrounds the tube through which the air ascends. Before we enter more fully into the merits of the Argand lamp, we shall give a description of it, with reference to drawings of its different parts. These drawings are taken from the lamps of modern construction, which have recently been much improved. The wick is now raised by a screw, instead of the rack and pinion; which is so great an improvement upon the latter, both in simplicity and convenience, that it is becoming general.

Fig. 1. (Plate Lamps) is a view of the lamp complete, to a scale of one-third the real size. A is a reservoir, which is on the principle of the bird-fountain, keeping the oil always at the same height in the burner B, through the communication C.

The burner B is composed of three tubes, *a*, *b*, and *c*. The two first are seen in section only; while the whole of one side of *c* is seen.

Fig. 2. The tube *c* is folded into the bottom of the tube *a*, and open throughout, communicating with the receptacle D, which screws on the outside of the tube *a*, and serves at once to catch the oil which may accidentally run over the tube *a*, and admit the air through the apertures *n*, *p*, which has to ascend through the tube *c*.

The oil which comes in through C will occupy the cavity *g* *h*, between the exterior surface of the tube *c*, and the interior of *a*, which must, of course, rise to the height of the aperture *t*, in the reservoir A, as seen in *fig. 3*. The part *de*, *fig. 2*, called the bucket, is a short tube to receive the circular wick. This part is seen in *fig. 4*, with the wick upon it, *df*. It is made to work freely upon the tube *c*. The latter has a spiral groove cut upon it, into which a pin at *o* enters; so that when the bucket is turned round by a catch *r*, which works in a longitudinal slit in *b*, it will be raised or lowered by turning the tube *b* in different directions, and is, therefore, the means of raising or lowering the wick.

A wire, *s*, is attached to the tube *b*, which bends down parallel to, and touching the outside of, the tube *a*. The part *klxy* fits upon the tube *a*. The part *kl* is provided with shallow sides to receive the glass E, and is connected with a ring *y*, by wires *x*, *z*, *fig. 1*. The whole of this part turns with the glass E, and at the same time carries round the tube *b*, by means of the wire *s*, which is connected to *kl* and *y*, for the purpose of raising or lowering the wick. When oil is to be introduced into the reservoir, A is screwed off, and inverted. The aperture *t*, *fig. 3*, is then opened, by pushing down the sliding socket *v*, which ought to fit the interior cylinder pretty accurately. The globe must now be filled at the hole *t*: the socket *v* is next pulled over the hole. The ball may now be held in an erect position, and replaced in the lamp; after which the socket *v* may be pushed below the hole *t*, by means of the handle *w*. The oil will now rise to a height in F, and in B, till it reaches the higher part of the aperture *t*, *fig. 3*, and will maintain the same height till the oil in the globe gets to the same level. The reason of this hydrostatical phenomenon will be easily perceived. When the oil in B and F gets a little below the aperture *t*, a bubble of air enters and ascends into the globe, the same quantity of oil descending to give it place.

This reservoir, although it is fully fitted for giving a re-

gular supply of oil, is attended with one disagreeable property. The air in the upper part of the globe being much more expandible by heat than liquid bodies in a warm room, its spring becomes greater than the pressure of the exterior air; in consequence of which, the oil is apt to flow over the tube *a*, and liable sometimes to overflow the vessel D. Another disadvantage is also attendant on this bulky reservoir. When the lamp is used on a table, the shadow renders one side of it useless. The above inconveniences in the Argand-lamp have been, in some measure, obviated by the invention of Mr. Peter Kier of Kentish Town. He raised the oil by means of a column of a heavier fluid. In the plate, *figs. 5* and *6*, are exhibited an elevation and section of one of these lamps; the section only requires to be explained. From the slender figure of the vase, it is evident that the flame is permitted to throw its light in all directions, downwards and upwards, nearly in the same manner as a candle. The interior part is divided into several compartments by the diaphragms at F and C. The space A A above F is open to the atmosphere; but the space B B, beneath C, is close. A tube F G proceeds from the space A A to the space B B, so as to reach nearly to the bottom at G, and another tube, C D, proceeds from B B upwards through A A, without communicating with this last space, and is enlarged at the upper part, so as to receive a wick with the apparatus of Argand, or any other. A solution of sea-salt, or the mother water of salt, being first poured in, by measure, at E, flows down the tube into B B, and fills that space. A like measure of oil is next poured, which also descends into B B, and forces the dense saline liquor upwards through G F into the space A A. The specific gravity of this last is adjusted by dilution; so that when the space A A is properly filled, the oil shall stand in equilibrio at the requisite height near E, viz. the surfaces in A and at E are elevated above the lower orifice at G, in the inverse proportion of the specific gravities.

This proportion is usually about three to four; so that if any of the oil be taken away from E by combustion, or otherwise, there will be a subsidence of the heavy fluid in A A to preserve the equilibrium; and during the whole subsidence in A A, there will be a correspondent depression of the upper surface of oil, near E, which will be measured by four-third parts of the first elevation of the dense fluid above the partition F D. Now, the fall in A A may be rendered very small, by enlarging the diameter of the vessel at that part, and at B B; and the elevation of E above A, and, consequently, the insulation of the radiant flame, may be governed at pleasure by prolonging the interval D C.

It is possible, in the manipulation of this lamp, that some oil, or pieces of snuff, may fall into the space A A, and float upon the liquid. This effect is, to a certain extent, beneficial, because the covering of oil prevents evaporation; but if this should require to be remedied, it is easily done, by pouring the whole contents of the lamp into a basin, and after a few moments repose, or straining, returning the liquids again into the lamp at E by a syphon, or funnel, in which they will take their proper places by means of their relative weights. We may recapitulate the good qualities of this lamp in a few words. 1. It is capable of any form or apparatus for the burners. 2. It presents no obstacle to intercept the emitted light. And, 3. As it raises the oil by the mere gravitation of a non-elastic fluid, it cannot, in any case, like the fountain lamp, raise more than is wanted.

A great variety of other lamps are at present exposed for sale, having different means of supplying the oil, but none so sufficiently striking as to merit minute description.

The grand and most essential properties of the lamp are confined to the means of supplying the flame with oxygen, so as to produce the most perfect combustion, and for which we are almost entirely indebted to *Argand*. We shall therefore conclude this article with some remarks upon the merits of this valuable invention, and shew in what instances it has been improved in its most essential points.

In the original lamp of Argand, a perpendicular column of air was perpetually ascending through the glass chimney of the lamp; one part of it passing through the central tube *c*, *figs.* 1 and 2; and the rest through the holes *q* and *m*, round the circular plate *k l*. This part was formerly a cylinder extending down to the receptacle D.

With this perpendicular current alone, it is well known that the Argand lamp would not burn *whale oil*, and the purification of this oil, to render it fit for the purpose, became a desideratum, on account of the high price of the spermaceti oil. This great object was not accomplished by purifying the oil, but an improvement was made in the lamp itself, which effectually answered the desired purpose. For this discovery we are indebted to an ingenious and scientific manufacturer of Derby. It is curious to observe, however, that no advantage was taken of this invention for twenty years, during which time it had been used in the cotton mills of this discoverer, and now the same end is accomplished by a simpler contrivance. The above improvement consisted in placing over the mouth of the tube *c* a plate of metal about the diameter of the tube, and at such a height as to be a little short of the apex of the flame. By this means the ascending column of air was turned out of its perpendicular course, and thrown immediately into that part of the flame where the smoke was formed, and which, by this means, was completely consumed, producing at the same time a more than ordinary brilliant light.

The same effect is now produced by the shape of the lamp glass E, in the figures already alluded to. The exterior current of air which enters the holes *q*, *m*, &c. rises with a velocity proportioned to the length of the glass chimney, and to the rarefaction of air in the flame, strikes upon the shoulders N and O, by which it is propelled into the upper part of the flame. This happy form in the glass appears to have been the result of accident. Had the manufacturer been aware of its importance, it would have either been the subject of a patent, or at least strongly recommended to the public in the way of puffing. We see at the present time different shaped glasses, some of which are rather worse than the original plan, instead of improvements.

The theory of the action of the chimney lamp, is so nearly allied to the principles of furnaces, which we have given under that article, that the reader will no doubt get some useful hints, relative to the construction of lamps, by perusing the same.

The hydro-pneumatic lamp is constructed upon similar principles to the celebrated water engine erected by father Hell, at Chremnitz, in Hungary; the descent of one-half of the fluid to a certain depth below the source, raises the other half an equal height above the source. This principle has been, with great success, applied to the lamp, we believe at first by the French, but has lately been brought to perfection by Mr. R. W. King, of Holborn, who manufactures these articles. *Figs.* 1, 2, and 3, of *Plate II.* explain the construction of this ingenious contrivance. *Figs.* 1 and 3 are sections to which our description will principally apply; A A is a cylindrical vessel, divided by horizontal partitions into four chambers, *viz.* B, C, D, and E. The upper one, B, is to contain the oil which is for the immediate supply of the

flame: the next, C, is for the portion of oil which descends into the inferior chamber E, through the pipe *a*, and forces the contained air up through the pipe *b*, into the upper chamber B, and pressing upon the surface of the oil contained therein, causes it to ascend the pipe *d*, to the lamp F, which is on Argand's principle, and of the same construction as before explained: *e* is a pipe to conduct the external air down into the chamber C; and *f* is a pipe to convey the waste oil, which may drip down from the lamp, into the middle chamber D, which is merely a reservoir for such waste oil. G is a tube passing down to the second chamber C, to fill it with oil; it is closed at pleasure by an air-tight plug *h*, fitting into the end of it; the lower orifice of the pipe *a* is closed by a piece of hat *i*, acting as a valve, which is shut by a spiral spring beneath it, but opened by a wire passing down the tube *a*, and also through the filling tube G, the plug of which, when in its place, presses down the wire, and opens the valve: suppose the plug removed, the spring will close the valve *i*. Oil is now poured in at the end of the pipe G; it runs down into the chamber C, and fills it, then rises in the pipe, which having a hole in one side, near its upper end, the oil also flows into, and fills, the upper chamber B. The plug *h* is now inserted into its place; this shuts off the communication of the open air, both with the chambers B and C, but depressing the wire, as before explained, opens the valve *i*, and the oil in the middle chamber C descends, by its gravity, through *a*, as shewn by the arrow, and enters the lower chamber E, from which it expels the air by the pipe *b*, into the chamber B. The end of this pipe being covered by an inverted hood, the air ascends by bubbles, through the oil, into the top of the chamber, and pressing on the surface of the oil, forces it up the pipe *d*, to the lamp in which it stands at the level of the dotted line *k*, at which level it will evidently continue, till the upper chamber is exhausted, and the contents of C descended into E. The lamp is now replenished by the following means; the whole apparatus is inverted, as shewn in *fig.* 3; the oil now runs down the pipe *b*, and filling its hood, flows over into the upper chamber B, which it fills, the atmospheric air entering the pipe *c* into the chamber C, and thence by the pipe *a* into the chamber E, the air contained in the chamber B escaping at the pipe *d*. The lamp is held inverted for about a minute, and is then set upright. Fresh oil is now poured in at the plug *h*, to fill the second chamber C, and then the plug being put in, the above operation is repeated.

By this ingenious application of the principles of hydrostatics, the lamp F is constantly supplied with oil at precisely the same level, which does not vary by any diminution of the quantity of oil, or by the expansion of the air by heat, as in the fountain lamp, the included air being only applied as the medium to transmit the pressure of one column of oil, from C to E to act upon, and raise a similar column from B to the dotted line *k*. The lamp is furnished with a glass chimney H, similar to that before described, and for some purposes this is surrounded by a glass globe K, ground within-side to take off the glare of the light. The cylindric vessel A A is included in an elegant columnar pedestal, shewn in *fig.* 2, where the ring L is that which is turned round to elevate the wick. *Fig.* 4. is a cap to cover the top, when the glass chimney is removed. The principal objection to this lamp, as originally constructed, was, that after inverting it, the oil would, in certain positions of the lamp, return down the pipe, and fill the lower chamber again, in which state it would not burn. Mr. King has completely remedied this, by bringing all the tubes, except the air and filling tubes, as near as possible into the centre of the lamp. Lamps of this

kind have been made to contain a sufficiency of oil to last two months, the vessel having the appearance of an elegant pedestal to ornament a hall or staircase.

A patent lamp, invented by John Barton, esq. is delineated in *fig. 5.* of our plate; it is contrived so as to always have a supply of oil maintained at a level, very near the point of combustion, by floating the oil upon a fluid of greater specific gravity. The oil is contained in a cylindrical vessel *A*, *fig. 5.* having a pipe, *B*, extending upwards from it to the burners at *a, a*, where the wicks are placed. The bottom of the vessel takes off with a screw joint, similar to a snuff-box, that the inside of the vessel may be cleaned; and in the centre of the bottom is an aperture of about half an inch in diameter always open. This oil-vessel is immersed in a heavier fluid, contained within the external vessel *D E F G*. A float is attached to the oil-vessel at *H*, and another, in addition to it, is fixed to the tube *B* at *I*. In this situation of things, the column of heavy fluid, (which may be salt water,) from its surface at *c* to *d*, where the oil presses upon it, (through the hole in the bottom of the oil-vessel,) will support a column of oil, of a greater height, in proportion to the difference of their specific gravities, from *d* up to *c* for instance, within an inch of the burners *a, a*, which is a sufficiently small distance for the capillary attraction to draw up a supply of oil to the wick. As the oil diminishes by burning, the water enters the hole in the bottom of the oil-vessel, and still continues to support the column of oil, as at first, the oil-vessel floating in the water by the floats at *H* and *I*. By this means it is freed from the inconvenience we have before ascribed to Mr. Kier's lamp, because the burners descend as the oil is consumed; and therefore, though the oil is not maintained at the same identical level, yet, with respect to the burners, it is always at the same distance below their wicks. The external vessel unscrews at *F*, to get in the oil-vessel *A*. The enlarged part or vase *D*, at the top, should contain very nearly, but not quite, as much as the oil-vessel. In preparing the lamp, the external vessel is first filled with the water (poured in at the top of the vase *D*) as high as *E*: the oil-vessel is now full of water, and rests upon the bottom, because the upper float *I* is not supported. The oil, being poured in at the top of the tube *B*, expels the water from the vessel, and fills it at the same time, raising the water in the vase *D*, and floating the oil-vessel. In this state the lamp will continue, with the oil standing at *s*, until it is all consumed.

A very simple and efficacious lamp has been lately presented to the public, under the title of the Automaton lamp, having something ingenious in the manner of supplying it with oil. We have given three figures of it at *figs. 6, 7, 8.* of the last plate; it consists of a tin box, *a b c d*, with a burner consisting of two wicks of cotton at *a*. The box is suspended upon pivots at *e*, entering eyes in the wire *f*, which is similar to the suspension part of a scale-beam. When this lamp is full of oil, which is poured in at *d*, it assumes the horizontal position *fig. 6.* because the mass of oil, *a b c d*, is chiefly situated behind the centre *e*, and balances the weight of the wick at *d*; but as the oil diminishes by burning, the weight behind the centre is lessened, whilst that of the wick continues without alteration. This occasions the lamp to librate, as in *figs. 7* and *8.* so that the oil is always kept very near the wick, by which means it will burn oil which is too impure for the capillary action of a common lamp. The nicety of its performance depends upon the figure of the vessel, and the place of the centre *e* corresponding with the weight of the tubes at *d*. This the makers have by experience determined to the greatest accuracy.

The Automaton lamp is in very general use in the north of England in cotton-mills, and other manufactories where the gas-lights are not introduced, which is undoubtedly the best method.

LAMP, *Cardan's*, is a contrivance of an author of that name, which furnishes itself with its own oil.

It consists of a little column of brass, tin, or the like, well closed every where, excepting a small aperture at bottom, in the middle of a little gullet or canal, where the wick is placed.

Here the oil cannot get out, but in proportion as it wastes, and so opens the passage of that little aperture.

This kind of lamp was much in use some years ago; but it has several inconveniences: such as that the air gets into it by starts and gluts; and that when the air in the cavity comes to be much rarefied by heat, it drives out too much oil, so as sometimes to extinguish the lamp.

Dr. Hook, and Mr. Boyle, have invented other lamps that have all the conveniences of Cardan's without the inconveniences.

The flame in a lamp never consumes the wick, till the wick be exposed to the air by the flame's falling downward; and from thence it may be inferred, that a way found out to keep the fuel, and consequently the flame, at the same height upon the wick, would make it last a long time. Many ways have been devised to arrive at this, but it seems only possible to be done, in any degree of perfection, by hydraulics. Thus, let a lamp be made two or three inches deep, with a pipe coming from the bottom almost as high as the top of the vessel; let it be filled so high with water, as to cover the hole of the pipe at the bottom, to the end that the oil may not get in at the pipe, and so be lost. Then let the oil be poured in, so as to fill the vessel almost brimful, which must have a cover, pierced with as many holes as there are wicks designed. When the vessel is thus filled, and the wicks are lighted, if water falls in by drops at the pipes, it will always keep the oil at the same height, or very near; the weight of the water being to that of the oil as 20⁸, to 19, which in two or three inches makes no great difference. If the water runs faster than the oil wastes, it will only run over at the top of the pipe, and what does not run over will come under the oil, and keep it at the same height. *Phil. Trans. No. 245, p. 388.*

The access of air is of the greatest importance in every process of combustion. When a lamp is fitted up with a very slender wick, the flame is small and of a very brilliant white colour: if the wick be larger, the combustion is less perfect, and the flame is brown: a still larger wick not only exhibits a brown flame, but the lower internal part appears dark, and is occupied by a portion of volatilized matter, which does not become ignited until it has ascended towards the point. When the wick is either very large or very long, part of this matter escapes combustion, and shews itself in the form of coal or smoke. The different intensity of the ignition of flame, according to a greater or less supply of air, is remarkably seen by placing a lamp with a small wick beneath a shade of glass, not perfectly closed below, and more or less covered above. While the current of air through the glass shade is perfectly free, the flame is white; but in proportion as the aperture above is diminished, the flames become brown, long, wavering, and smoky; it instantly recovers its original whiteness when the opening is again enlarged. The inconvenience of a thick wick has been long since observed, and attempts have been made to remove it; in some instances by substituting a number of small wicks instead of a larger; and in others, by

making the wick flat instead of cylindrical. The most scientific improvement of this kind is the lamp of Argand, described in the preceding part of this article. In this the wick forms a hollow cylinder or tube, which slides over another tube of metal, so as to afford an adjustment with regard to its length: when this wick is lighted, the flame itself has the figure of a thin tube, to the inner as well as the outer surface of which the air has access from below. And a cylindrical shade of glass serves to keep the flame steady, and in a certain degree to accelerate the current of air. The inconvenience of a long wick, which supplies more oil than the volume of flame is capable of burning, and which consequently emits smoke, is seen at once by raising the wick; and on the other hand, the effect of a short wick, which affords a diminutive flame merely for want of a sufficient supply of combustible matter, is observable by the contrary process. The most obvious inconvenience of lamps in general, arises from the fluidity of the combustible material, which requires a vessel adapted to contain it, and even in the best constructed lamps is more or less liable to be spilled. When the wick of a lamp is once adjusted as to its length, the flame continues nearly in the same state for a very considerable time. Nicholson's Journal, vol. i. 4to.

By 17 Geo. II. cap. 29. a convenient number of glass lamps shall be put in such places of the city of London, as the mayor, aldermen, and commonalty shall think fit; to be kept lighted and burning from sun-set to sun-rising throughout the year; and rates shall be made not exceeding 6d. in the pound, nor above 50s. a year on any one person, for defraying the charges of them. Every alderman, with consent of his deputy and common council, may contract yearly for the setting up lamps, and their lighting, trimming, &c. and persons maliciously breaking down or extinguishing the lamp, shall forfeit 40s. for the first offence; 50s. for the second; and 3l. for the third, leivable by justices, or to be sent to the house of correction. By stat. 11. Geo. III. c. 29. for paving and lighting London, the wilfully breaking or extinguishing of any lamp incurs the penalty of 20s. for each lamp or light destroyed or extinguished. None but British oil is to be used for lamps in private houses, under penalty of 40s. 8 Ann. cap. 9.

The use of lighted lamps in churches, and places of devotion, is very ancient. In the city of Fez is a mosque, wherein are 900 brazen lamps burning every night. In Turkey, all the illuminations are made only with lamps. Polydore Virgil ascribes the first invention of lamps to the Egyptians; and Herodotus describes a feast of lamps held annually in Egypt.

Kircher shews the manner of preparing lamps, which shall diffuse a light so disposed, as to make the faces of those present appear black, blue, red, or of any other colour.

There has been a great dispute among the learned about the sepulchral lamps of the ancients: some maintain, they had the secret of making lamps that were inextinguishable, alleging several that have been found burning, at the opening of tombs fifteen or sixteen hundred years old. But others treat these relations as fables; and others think, that the lamps, which were before extinguished, took light afresh upon the admission of fresh air.

Dr. Plott, however, is of opinion, such perpetual lamps are things practicable, and has himself made some proposals of this kind. The *linum asbestinum*, he thinks, may do pretty well for the wick, and that the naphtha, or liquid bitumen, constantly springing into some of the coal-mines, would answer for the oil.

If the asbestos will not make a perpetual wick, he thinks

there is no matter in the world that will; and argues, that the tradition of such lamps must be fabulous, or else that they made them without wicks.

Such a lamp he thinks it possible to make of the bitumen springing into the coal-mines at Pitchford, in Shropshire; which, he says, like other liquid bitumen, will burn without a wick.

Those lamps that kindle on the immision of fresh air, the same author thinks, might be imitated by inclosing some of the liquid phosphorus in the recipient of an air-pump; which, under those circumstances, will not shine at all; but on letting the air into the recipient, there will possibly, says he, appear as good a perpetual lamp as some that have been found in the sepulchres of the ancients.

LAMP, *Rolling*, in *Mechanics*, is a lamp A B (Plate I. Lamps, fig. 7.) that has within it the two moveable circles D E and F G, whose common centre of motion is at K, where their axes of motion cross one another, in which point also is their common centre of gravity. If to the inward circle you join within the lamp K C, made pretty heavy, and moveable about its axis H I, whose centre of gravity is at C, the common centre of gravity of the whole machine will fall between K and C, and by reason of the pivots A, B, D, E, H, I, will be always at liberty to descend; and, therefore, let the whole lamp be rolled along the ground, or moved in any manner, the flame will always be uppermost, and the oil cannot be spilt. In this manner the compass is hung at sea; and thus should all the moon-lanterns be made that are carried upon a pole before coaches or carriages which travel in the night. Desag. Exp. Phil. vol. i. p. 57.

LAMP-black. Of this kind there are two sorts; one of which is the light foot, obtained from burning pine and other resinous wood; and another, which is the heavy black, obtained by calcining bones in close vessels. See BLACK. See also BONE and CHARCOAL.

LAMP-blowers are persons who form various articles of glass for toys, and for more important philosophical purposes, from tubes, &c. by means of the *blow-pipe*; which see.

The apparatus of these artists consists of a solid table, to the bottom of which is fixed a double bellows with a foot-board, from which proceeds a pipe that conducts the blast to the lamp. This lamp is a large bundle of cotton threads, placed in a tin vessel in the shape of a horse-shoe, and supplied by lumps of tallow deposited by it, and pushed into the flame as the continued combustion requires. The smoke is conveyed away by a small chimney suspended over the lamp. The blast-pipe in front of the table, at which the artist is seated, drives the jet of flame away from him, so that he suffers no inconvenience from it.

The other articles of his apparatus are glass tubes of various dimensions, and two or three very simple iron tools, such as a small forceps, files, &c. The flame in full vigour is about four inches in length, which near its extremity is of a clear light blue, when it is the hottest, and beyond of a pale yellow. The tubes, before the operation commences, are well dried, so as to be quite free from moisture. They are then gradually heated by being first held in the flame of the lamp without blowing, and then at the edge of the outer yellow part of the jet of flame, and slowly brought to a state of fusion. The flame is sufficiently strong to bring to a very white-red heat a solid mass of glass, about the size of a playing marble, or even larger; and this, when blown out very thin, will make a bulb of the capacity of three ounces, which is nearly the extent of the power of the common lamp-blowing. The bulbs for thermometers and other phi-

lofophical purposes are much less. (Aikin's Dict. vol. i. art. *Glass*.) For an account of the operation of hermetical sealing, performed by the lamp-blowers, see **HERMETICAL Sealing**. For bending and joining glass-tubes, forming bulbs to tubes, and spinning out glass-threads, see **TUBE**, **THERMOMETER**, and **THREADS**.

LAMP furnace, is a furnace, in which the heat is produced and maintained by the flame of a lamp introduced within it.

This furnace has no occasion for an ash-hole, a grate, or a fire-place. It has only one opening below, through which the lamp is introduced, and a kind of small chimney in its upper and lateral part, for circulation of air, to keep up the flame of the lamp, and to give vent to the smoke. For the description of an improved furnace of this kind, see Lewis's Com. Phil. Techn. p. 29. See **FURNACE**.

Argands.

Fig 1

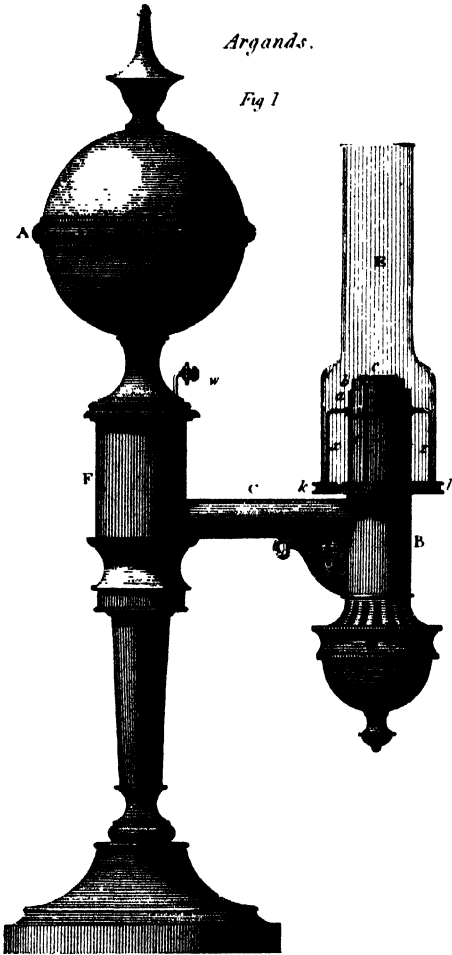
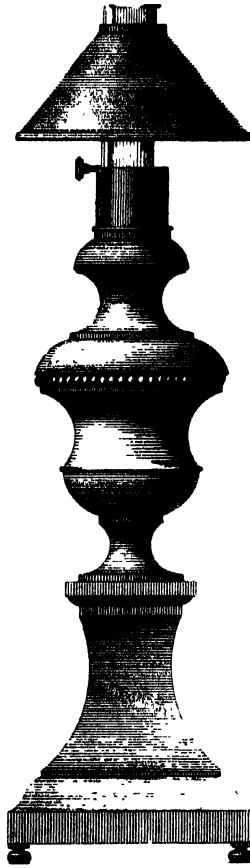


Fig 6.



M^r Kier's.

Fig 5.

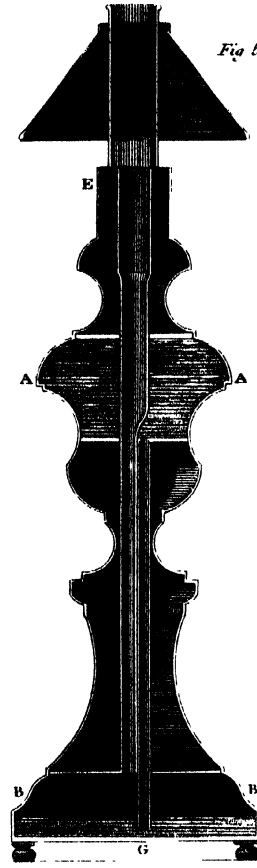


Fig. 3.

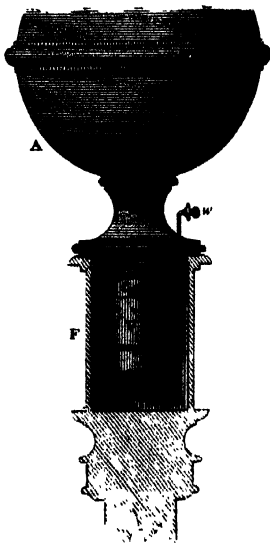


Fig 2.

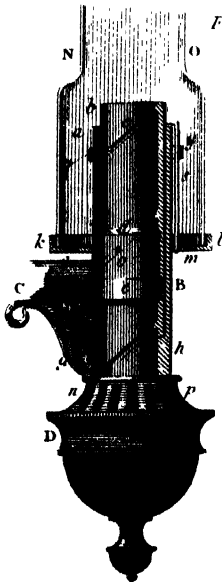
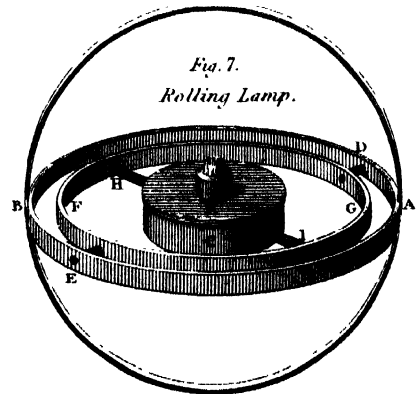


Fig 4
Lamp Cotton.



Fig. 7.
Rolling Lamp.



L A M P S .

PLATE 1

Hydro-Pneumatic Lamp by R. W. King.

Fig. 1.

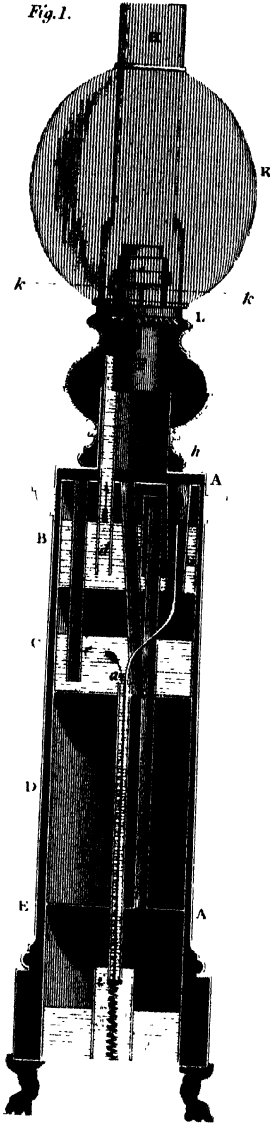


Fig. 2.

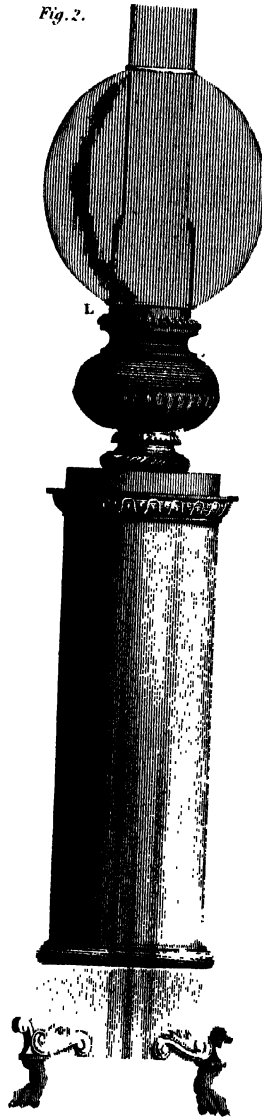


Fig. 4.



Fig. 3.

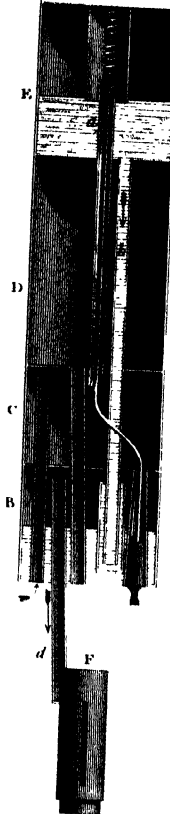


Fig. 5.

Mr. Barton's Lamp.

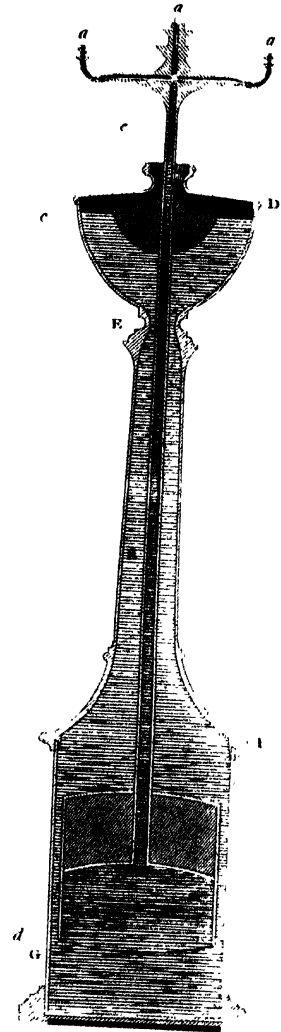
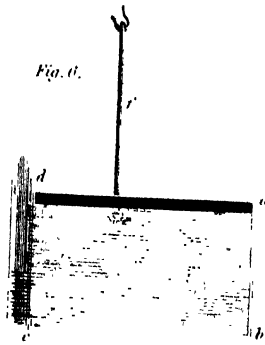


Fig. 6.



Porter's Automaton Lamp.

Fig. 7.

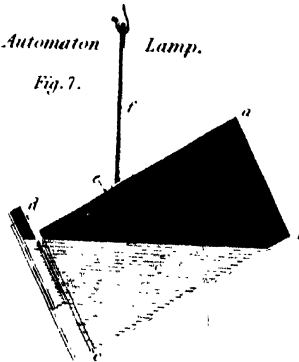
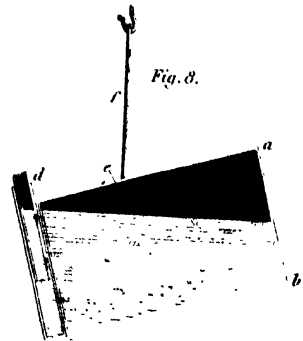


Fig. 8.



Lanarkshire

LANARKSHIRE, an inland county in the south of Scotland, is frequently denominated *Clydesdale*, from the river Clyde, which flows through it longitudinally in a winding course of more than sixty miles. The situation of this county is between $55^{\circ} 22'$ and $55^{\circ} 58'$ north latitude, and between $3^{\circ} 15'$ and $4^{\circ} 19'$ west longitude. It is bounded by Dumfriesshire on the south, by the shires of Ayr and Renfrew on the west, by the counties of Dunbarton and Stirling on the north, and by those of Linlithgow, Edin-

burgh, and Peebles on the east. Its length from north to south is about forty-seven miles, and its breadth nearly thirty-two. The parishes it contains are forty-eight in number, inhabited, according to the parliamentary returns in 1800, by a population of 150,690 persons. The surface contents are 927 square miles, or 593,280 statute acres. Lanarkshire anciently formed a great portion of one of the principalities into which Scotland was divided at the time of the Roman invasion. The name given to this kingdom was Strathclyde, which comprehended, besides the county of Lanark, those

of Stirling, Dumbarton, and Renfrew. This shire is divided into three districts, or wards, formerly known by the appellations of Clydesdale, Douglassdale, and Avondale, but these are now more frequently termed the upper, middle, and lower wards. Each of these districts is subject to the particular jurisdiction of a substitute appointed by the sheriff-depute of the county.

With respect to the *soil* and *appearance* of this county, the upper parts of it, except in the vicinity of the Clyde, are so hilly and moorish, as scarcely to be susceptible of any improvement from agriculture. The elevation of the hills is in general very great; some of them rise to the height of 600 feet above the level of the sea. Notwithstanding this, they exhibit but little grandeur, the perception of their size and altitude being much modified by the closeness with which they are crowded together. The chief part of the arable lands in the upper district, lies in the parishes adjoining to the hill of Tintoe, round which the Clyde flows with a slow and gentle current, washing, in its course to Lanark, twelve miles of the finest meadow-lands in Scotland. In the neighbourhood of Biggar, one of the towns in this district, the soil is uncommonly rich and fertile. This fertility is in many places principally owing to the inundations of the Clyde, which are likewise often the source of irreparable damage, by carrying off, not only the crops, but even the very soil it had formerly enriched. Proceeding down the river, the soil is found to be dry, light, and friable, but less productive than in the vicinity of Tintoe. Carlicke parish is of a clayey soil, but excellent in quality. This parish, and indeed all the parishes situated along the river, are particularly distinguished for the richness and variety of their scenery. Within this district are the falls of the Clyde, celebrated both by the poet and the painter. Above, as well as below these falls, the banks of the river are adorned with numerous country seats, and villages filled with industrious inhabitants.

The middle ward, or district of this county, is not nearly so elevated as that above mentioned. When viewed from any considerable height, indeed, it has the appearance of a level country, though in fact it is much diversified with hill and dale, the former being much less abundant than the latter. The soil of this ward is in general of a clayey texture, and within six miles of the river extremely fertile. The scenery here is no less beautiful than that of the upper ward, the banks of the Clyde being covered with hamlets, orchards, and plantations of various kinds: beyond the range of six miles, however, the country is of a very different description. It is supposed that there are not less than 40,000 acres of moss-land within this district, and such spots as are free from that covering, display a soft clayey soil, formed from a sort of hard clay, lamellated in a horizontal direction, which is called by the farmers *till*, and is known to mineralogists by the name of *schistus*.

The lower ward is extremely limited in extent, but may rank as the most important of the three, on account of its containing the city of Glasgow, which is justly denominated the Manchester of Scotland, and is perhaps scarcely inferior to Liverpool in point of commercial importance. The lands in this district are naturally barren and unproductive, but in the neighbourhood of Glasgow, the overflowings of a very prosperous commerce have added greatly both to its scenery and fertility. See GLASGOW.

The chief towns in Lanarkshire are Glasgow, Lanark, Rutherglen, Hamilton, Douglas, Biggar, and Carnwarth. Of these the three first are royal boroughs, and will be found described under their respective names. Many considerable villages are likewise scattered throughout the county. The most worthy of notice among these are those of Leadhills and

Wilson-town, which are indebted for their prosperity to the mineral productions of the county. *New Lanark*, which owes its origin to the cotton works established there by David Dale, esq of Glasgow, is also a thriving and populous place. These works were first erected in the year 1785, and are perhaps the most extensive of their kind in Scotland. They afford employment to upwards of 1500 persons, many of whom are children. Great attention is paid to their morals and education. The situation of the mills is extremely singular and romantic, being nearly surrounded by high grounds of very steep ascent. They were built on this spot chiefly on account of the great command of water that could be obtained. For this purpose a subterraneous aqueduct has been cut through the solid rocks, for the space of several hundred yards. Both the works and the scenery around are objects of peculiar interest and curiosity. One of the mills contains no less than 6080 spindles.

Besides the Clyde, already so often mentioned, there is a number of other streams in this county, all of which, however, discharge themselves into that river. The chief of those on the northern side are, the Elwin, Glengonan, the Little-Clyde, the waters of Duneaten and Coutten, and the two Calders. None of them are remarkable, except that the two latter are well shaded with wood, and adorned with a number of neat villas. The streams on the southern side of the river are rather more deserving of attention. The Mous-water is particularly remarkable for that part of its banks called Cartlane-Craigs. These form a curious and romantic den, or dell, somewhat more than a quarter of a mile in length. The rocks on either side rise to the height of four hundred feet, exhibiting a terrific and rugged appearance in one spot, while, in another, the eye is relieved by a pendent covering of coppice wood. At the bottom runs the river Mous, so closely confined as scarcely to allow room for the lonely traveller to traverse the den. At all the windings of this river the scenery varies, and whenever a rock is found to project on one bank, a corresponding recess may be seen on the other. One of these caverns is still called "Wallace's Cave," from a tradition of its having been for some time the place of that hero's concealment. Logan-water, which rises in the mountain separating the parish of Lefmahago, from that of Muirkirk in Ayrshire, is a beautiful pastoral river. The Avon, which likewise takes its rise on the confines of Ayrshire, after being joined by several minor streams, empties itself into the Clyde near the town of Hamilton. In its course it passes through the inclosures of the duke of Hamilton, where its bold and lofty banks, covered with a variety of shrubs and trees, afford many extremely fine and picturesque views.

No county in Great Britain is more interesting to the geologist, or abounds with a greater variety of *mineral productions*, than Lanarkshire. The surface of the upper division of the county generally rests upon whinstone, standing in perpendicular columns. The middle and lower districts, for the most part, exhibit some kind of freestone for their base, but are intersected, at different points, by ridges of whinstone running off from the rocky mountains, downwards, throughout the whole extent of the county. Under the strata of freestone immense strata, or beds of *coal*, are discovered, extending over all the plain country, and branching out, more or less, along the course of the principal waters. The seams of this useful mineral are not entirely of one kind. Where the whole strata remain untouched, a variety of thin and less valuable seams, or strata, present themselves in digging down to what is commonly called the *upper coal*, because it is the first that is found to be worth mining for to any extent. This stratum is composed of the *rough coal*,

except a small portion in the middle of it, which is of the kind called splint. After this, comes the *ell coal*, which is much esteemed for the blacksmith's forge. At from ten to seventeen feet beneath this stratum, the seam called the *main coal* is found. It is so named because it possesses all the good qualities of the other strata, and is preferred, by consumers in general, to every other species of this mineral. Below the main coal are four more seams. The highest of these is composed of the *hump coal*, the second of the *hard coal*, the third of the *soft coal*, and the fourth and last seam of the *lean or four-milk coal*. Beneath all are found several strata of excellent limestone, probably as extensive and inexhaustible as the valuable mineral which covers it. Independently of these strata of coal in the plain, there are others in the higher grounds, but of a dissimilar nature and arrangement. The hills in the parish of Shotts, like the tracts of the same elevation in the upper ward, are found to consist of an enormous bed of whinstone, but in descending along their sides, the freestone rock shows itself lying in a horizontal position beneath the whinstone. Below the free-coal, ironstone and limestone are discovered in such vast profusion, as seemingly to defy the utmost efforts of human industry to exhaust them. Near the Douglas river also, extensive collieries, similar in quality to those of Shotts, are wrought, which supply the higher districts of this county and Tweeddale, where no coal has yet been discovered. To the vast supplies of this valuable mineral, and its consequent cheapness, the manufacturing prosperity of the west of Scotland is to be principally attributed, as, without abundance of fuel, scarcely any manufacture can be carried on.

Lead and Iron.—Another great source of industry and opulence bestowed on this county by nature, is derived from its mines of lead and iron. The former of these metals is chiefly wrought at Lead-hills, a range of mountains in the uppermost part of the county, immediately adjoining to Nithsdale. These mines belong to the earl of Hopetoun, and are carried on by two separate companies. The number of miners employed in them is very great. They work only six hours out of the twenty-four, so that they have much leisure time, a great portion of which is dedicated to reading. To facilitate this worthy employment of their time, a library was established many years ago by an overseer named M^r Sterling, who prevailed on the workmen to subscribe for that purpose. Since that event the miners have been remarkable for industry and sobriety of manners, the usual concomitants of a taste for literature; and the example has been followed with similar effects at the neighbouring mines of Wanlockhead.

The iron of this county is found every where in the same tract with the strata of coal. In many places it is imbedded between the different seams of that mineral, and is usually wrought at the same time with it. Iron ore, that is, the metal in its richest state, has not yet been discovered here in any great quantity, but ironstone exists in great profusion. It is found either in the form of beds of rock, or in collections of nodules or ironstone balls, as they are called by the workmen, of various shapes, size, and qualities. Among these balls is the curious fossil called *ludus Helmontii*, *septuarius*, or *waxen veins*. It is of a spherical shape, more or less oblate or depressed. Above and below them are alternate strata of ironstone and schistus. They lie on their depressed sides, in a regular direction, making a sort of interrupted stratum, one stone being several inches and some even a foot or two distant from the other. The ironstone of which they are composed is of excellent quality, yielding sometimes fifty *per cent.* of iron.

The *Antiquities* in this county are not so numerous, in pro-

portion to its extent, as in some other counties of Scotland. The Roman road, which formerly crossed the parishes of Lamington and Biggar, and descended along the south bank of the Clyde, is now only visible in a few detached spots. Different parts of the upper wards, in particular, abound with excavations in the earth, or vaults which were used as strong holds by the aboriginal inhabitants, when the haughty chieftains of Clydesdale and Annandale were engaged in mutual hostilities and depredations. At Cold-chapel are the remains of a Roman station, and in the same neighbourhood is a spot called Wallace's Camp. It is said that a chair, which formerly belonged to that hero, is still preserved at Borrrington.

Near Biggar are several artificial mounds. The church of that town is one of the most venerable relics of monastic architecture in Scotland. Here is preserved an ancient vase or urn, supposed to be Roman, which was usually appropriated to sacred purposes by the Popish priests. Boghall castle, about a mile from this church, was formerly surrounded by a marsh, and accessible only by a causeway or mound of earth. The entrance is through a large and magnificent gate-way, which leads into a spacious court in the centre. This castle is flanked with towers. It was formerly the residence of the Flemings, earls of Wigton, and has evidently been one of the most extensive and splendid fortresses in Scotland. This neighbourhood is represented in the popular histories of sir William Wallace, as having been the scene of a sanguinary conflict between his band of patriots and the army of Edward I.

Cuthally castle, or, as it is vulgarly called, Cowdaily castle, the seat of the ancient family of Somerville, is situated in the parish of Carnwarth, and appears to have been formerly a place of great strength. At the foot of Tintoe is an artificial mount, and near it a circle of large stones set up perpendicularly. On an adjacent farm is a place called Sheriffs' flats, where it is supposed the sheriffs anciently held their courts. Tradition reports, that a bullock's hide, full of gold, is buried under this spot. Here are also the walls of a castle which belonged to the family of Lindsay. In Pittmair parish are the vestiges of a large encampment, the figure of which approaches to a circular area. A small fort belonging to it is still distinctly visible at a little distance from the walls. Several urns have been lately found here inclosed within four large flag stones. At Douglas are the remains of a castle belonging to the powerful family of that name. The greater part of this building was unfortunately consumed by fire about fifty years ago. In the old church of St. Bride's, in Douglas, are a number of monuments in honour of the Douglasses. The parish of Carstairs, in the vicinity of the Clyde, contains the vestiges of a Roman camp, the causeway leading to which can still be traced for many miles. Pots and dishes of different kinds, as well as various instruments of war and sacrifice, have been discovered here. A number of coins have also been dug up, bearing the inscription of Marcus Aurelius, and Marcus Antoninus. At Cleghorn is another Roman camp, supposed by general Roy to have been the work of Agricola. Besides these remains of antiquity there are a number of others; as the priory of Lesmahago, the castles of Cudzow and Avondale, &c. but the limits of this article will not allow us to particularise the whole. Many of them, however, will be found either described or noticed in our accounts of the respective places. Rothwell castle, in this district, is one of the most magnificent ruins in Scotland. The structure itself is superb, and all the objects around have an aspect of grandeur. The whole work is executed with smooth stone of a red colour. It is adorned with lofty towers at both

ends, and has undoubtedly been a place of considerable strength.

The principal seat in Lanarkshire is the palace of Hamilton, belonging to, and the occasional residence of, the Hamilton family. It is a large massive pile, of a dull and heavy appearance, situated in the neighbourhood of the town, from which it derived its name, and deserves notice chiefly on ac-

count of the beauty of its scenery, and the valuable collection of paintings it contains.

Lanarkshire has long been celebrated for its horses, which are reckoned among the most powerful in the world. As containing the town of Glasgow, it must be ranked among the first manufacturing and trading counties in Great Britain. Forsyth's Beauties of Scotland, vol. iii.

Lath

LATH, in *Building*, slips of wood used in plastering, tiling, and slating. These are what Festus calls *ambrices*; in other Latin writers they are denominated *templa*; and by Gregory of Tours, *ligatura*.

In plastering, the narrower the laths are the better they are for the purpose, so as they are of sufficient breadth to hold the nails, as the number of interstices are increased, the lime or stuff will hang more readily, and the thicker they are they will be the better adapted to resist violence; but then they would be much more expensive. The laths are generally made of fir, in three, four, and five feet lengths, but may be reduced to the standard of five feet. Laths are single or double; the latter are generally about three-eighths of an inch thick, and the former barely one quarter, and about an inch broad. Lath is sold in bundles; the three feet are eight score to the bundle, four feet, six score, and the five feet, five score. The lath for plain tiling is the same as that used in plastering. Laths are also distinguished into heart and sap-laths; the former should always be used in plain tiling, and the latter, of an inferior quality, is most frequently used by the plasterer. Heart-of-oak laths, by the statute Edw. III., should be one inch in breadth, and half an inch in thickness: but now, though their breadth be an inch; so that two laths, as they are now made, are but equal to one lath. According to the said statute, pan-tile laths are nine or ten feet long, three-quarters of an inch thick, and one and a half inch broad, and should be made of the best yellow deal: the bundle consists of twelve such laths. A square of plain tiling will require a bundle of laths, more or less, according to the pitch. The distance of laying laths one from another is various, differing more in some places than in others; but three and a half, or four inches, are usual distances, with a counter-lath between rafter and rafter: but if the rafters stand at wide intervals, two counter-laths will be necessary. Laths are employed for various other purposes as well as plastering and tiling, as in filleting for

sustaining the ends of boards; in naked flooring and roofing; for furring up the surfaces; and in every kind of small work, where the dimensions of the parts do not exceed the scantling of laths.

In lathing for plastering, it is too frequent a custom to lap the ends of the laths upon each other, where they terminate upon a quarter or batten, in order to prevent cutting them; but though this practice saves a row of nails, it leaves only a quarter of an inch for plaster, and if the laths are very crooked, as they frequently are, there will be no space whatever left to straighten the plaster: the finished surface must, therefore, be rounded, contrary to the intention and to the good effect of the work; but if the ends are to be laid upon each other, they should be thinned at the lapping out to nothing at the extremity, or otherwise they should be cut to exact lengths.

Laths should be as evenly split as possible; those that are very crooked should not be used, or the crooked part should be cut out; and such as have a short concavity on the one side, and a convexity on the other, not very prominent, should be placed with the concave side outwards.

The following is the method of splitting laths: the lath-cleavers having cut their timber into lengths, they cleave each piece with wedges into eight, twelve, or sixteen pieces, according to the scantling of the timber: the pieces thus cloven are called bolts; then, in the direction of the felt-grain, with their dowl-ax, into sizes for the breadth of the laths: this operation they call felting; and, lastly, with their chit they cleave them into thickness by the quarter-grain.

LATH Bricks are bricks made much longer than the ordinary sort, and used instead of laths for drying malt upon; for which purpose they are extremely convenient, as not being liable to catch fire, and retaining the heat much longer than those made of wood, so that a very small fire is sufficient after they are once heated.

Lathe

LATHE, an engine of the most extended application in the mechanic arts, for forming wood or metal into any article of a circular figure. The mode of action in a lathe is essentially different from any other method of cutting, as the work is caused to revolve in a circle, while the tool is held upon a fixed support, and presented to it to cut away any parts projecting beyond the circle described by the motion of the work. To the mechanic the lathe is an invaluable machine, as a very great proportion of all the parts of machines is formed in it, and as it is the only method of working metal which may be considered as perfect. All things which can be turned are made in the lathe, both for accuracy and expedition. The common wooden lathe, in use among wood-turners for making articles of household furniture, is so generally understood, that it is needless to give a minute description of it; we have, therefore, given drawings in *Plate (Lathe)* of a metal lathe, the most perfect of its kind, proper for turning accurate and delicate works for mathematical instruments, or machinery: it was made by Mr. H. Maudslay, London, who has a great number of different sizes, but on a similar construction, in constant use, at his manufactory for steam-engines, and other machinery, in the Westminster-road. *Figs. 1. and 2.* of the plate are a front and end elevation of the whole lathe, where A A is a strong mahogany bench, supported on iron standards B, B, which are shewn fully in *fig. 2*; beyond these are suits of drawers C, C, to contain the tools, &c.: the standards B

carry the axis D of the great foot-wheel E, which gives motion to the work when it is turned by its crank D and treadle F, on which the workman presses his foot, at intervals, to turn the wheel round. The lathe itself, which is fixed upon the bench, consists of a triangular bar G. See also *fig. 3*, which is an enlarged figure of it; it is supported on small standards *a, b, c*, fixed to the bench A by screws going through it: upon this bar the puppets H, I, and K, are fitted with perfect accuracy, and H, which is called the back puppet, can be fastened at any part of the bar by a screw beneath it; the other two puppets, I, K, are screwed down upon the standards *a* and *b*, and are connected together by a piece of metal *d* fitting upon the bar, and cast in the same piece with them: these two puppets support the mandrel, or spindle L, one having a screw with a conical steel point to enter a hole in the end of the spindle, and the other having a hard steel collar to receive the neck of the spindle, which fits it with the most perfect accuracy, to turn round freely (by a band encompassing its pulley M), but without any shake in its collar; on the end of the spindle, beyond the collar, is a small screw to fix on the work to be turned. The back puppet H has a hole through the top of it, exactly in a line with the spindle, and a steel pin *e*, with a conical point fitted into it to support the end of a long piece of work; the point is fastened by a screw *g* in the top of the puppet, and has a screw *f* behind it to force it forwards: the bar G, also, has the right, or support, for the tool fixed upon it, by a piece of metal *g*, (*fig. 1.*) fitted upon

the bar; a slider is fitted upon this piece to slide in a direction perpendicular to the bar, and the same screw beneath fastens the rest upon the bar at any place, and the slider at any length across the bar. On this slider is a socket to receive a pin, on the top of which is a cross-piece, formed like a T, upon which the tool is laid; this T can be adjusted to the height of the work the tool is to be applied to, and can be fastened at any height by the screw in the side of the socket. The various kinds of work to be turned are fastened to the end of the spindle, so as to be turned round with it, by means of what are called chucks: these are pieces of wood, or metal, fitted to screw fast upon the end of the spindle, and a hollow, like a dish, being turned out in it; the piece of wood or metal to be turned is driven into this hollow, and thus held to be turned, by holding a tool over the T of the rest, which is previously fixed close to the work, and presenting the edge to the work as it revolves by the treadle F, turning the foot-wheel, &c.: thus, by its band turning the pulley M, and the work with an increased velocity. A chuck of this description is shewn mounted in *fig. 1*, with what is supposed to be a plate of brass, held in it to turn the flat face. Some chucks are flat, with holes through them, and the work is held by screws against it; others are provided with three jaws, like a vice, which can be altogether caused to advance to, or recede from, the centre, by turning a screw, so as to encompass a piece of work of any dimensions. This method of chucking is adopted to form all kinds of flat or hollow work, as cups, boxes, circular rings, or plates, wheels, &c. which are, therefore, termed chuck-work; but articles of considerable length are supported at both ends, which method is called turning between centres. In this method the puppet H is slid along the bar to the length of the work, and fixed there by its screw: the point *e* is now, by its screw *f*, thrust forwards, and its point enters a small hole, previously drilled in the end of the work: the screw *g* is now tightened, to fasten the point *e*, upon which one end of the work revolves as a centre, the other end is received into a square hole in the end of a chuck screwed to the spindle. In other cases, the spindle has a chuck screwed to it, terminating in a conical point similar to that at *e*; this forms a support for the end, and an arm, projecting from the chuck, intercepts a pin or arm fixed to the work, and by this means turns it round with the spindle. This method of turning between centres is employed to turn spindles of wheels, bolts, screws, rollers, the outides of cylinders, or any other articles of greater length than their diameter. When a piece of work is to be turned, which is larger than the lathe will admit, the bar is to be drawn out, as in *fig. 1*, and supported by an additional standard *c* screwed to the bench. In the same state it will admit longer work.

The particular manner of holding the tool to the work is not easy to describe in words, but is soon acquired by practice. The tools for brass are square or flat bars of steel, the ends of which are cut off obliquely, to form an edge like a chisel, but with a very obtuse angle. It is held in such a position, that its upper flat surface points to the centre of the work to be turned: it is to be held down as firmly as possible to the rest, and advanced to the work at intervals, whenever it ceases to cut, by having removed all the projections of the work without the circle it describes. For turning with extreme accuracy, the slide-rest is a very useful addition to the lathe. It is a rest with two sliders in different directions, to one of which the tool is fixed: by means of screws with handles, the sliders and the tool can be moved in either direction, to bring the tool to the work. *Figs. 3, 4, and 5*, explain the ingenious piece of mechanism. NA

is a piece of metal, fitted to the bar of the lathe, and provided with a screw to fasten it at any place: upon the upper surface, which is flat, two pieces of brass are screwed, to form a dove-tailed groove, in which a slider, *b*, is fitted, to move with freedom and precision; a screw, *i*, is mounted in the frame N, and is lapped into a piece projecting from the lower side of the slider, so that the screw, when turned round by a handle fitted on its square, advances or draws back the slider in its groove. Upon this slider, *b*, is a frame *k*, having at the top of it a slider *l*, provided with a screw *m*, as the former, to move it, and carrying a piece *n*, with square holes through it in two directions to receive the tool *o*, and a screw at top to fasten it in. The slide-rest being mounted, in the manner of *fig. 3*, upon the bar, the upper slider, *l*, is parallel with the spindle, and the lower one, *b*, perpendicular thereto. For turning flat work, the tool is put in as there shewn: now by turning the screw, *m*, of the upper slider, the tool is advanced in contact with the work, which is mounted as in *fig. 1*; then by the other screw, *i*, it is drawn across the face of the work, turning it as it proceeds, to a perfectly flat surface. For turning a cylinder between centres, the tool, *o*, is put through its holder *n*, in a direction perpendicular to that shewn in *fig. 3*; and then the lower slider, *b*, is moved to adjust the tool to the diameter of the intended work; and the upper slider is moved, to carry the tool along the length of the cylinder, and cut it as it goes. The slide-rest will also turn cones, by the following contrivance: the frame *k*, supporting the upper slider, is fitted to the lower slider by one pin, upon which the whole frame and upper slider may be turned round and fastened at any inclination, by two screws passing through circular grooves. By this means the upper slider is inclined in any angle to the spindle, to turn a cone either hollow or solid, as the tool is put into its holder in one or other direction.

The slide-rest can be made to cut screws by an ingenious application, which is explained in *figs. 6 and 7*. A short bar P, exactly of the same dimensions as the large one, is fitted thereon, and fastened by its screw *p*. Upon this the slide-rest is placed: its sliders now stand in a direction perpendicular to what they did before, though on the same level. The screw to be cut, represented by Q, *fig. 6*, is mounted between the centres, and turned to a true cylinder by a tool put in the holder *n*, and carried along parallel to the spindle, by turning the screw, *i*, of the lower slider: this being done, a cog-wheel, V, is fitted on the chuck, at the end of the spindle, and another, W, is attached to the end of the screw, *i*, of the lower slider, so that it will be turned round at the same time with the spindle. A tool, with a point of the proper form to cut the thread of the screw, is put in the holder *n*, and advanced by the screw, *m*, of the upper slider to touch the cylinder Q. The lathe being now put in motion, the tool is moved along by the screw of the lower slider, at the same time the work revolves, and upon which it traces a spiral groove. When it arrives at the end of the screw, which it only scratches the first time, the tool is drawn back clear of the work, and the lathe turned the contrary way, to return the tool to the place where it first set out. The tool is then set by the screw *m*, to cut deeper than the first time, and the screw is cut over again: this being repeated four or five times, the screw is completed. By this method a screw of any degree of fineness may be cut, by merely changing the proportion of the cog-wheels, V, W, which connect the spindle and the screw of the lower slider. It is plain, if these wheels are of equal size, a screw will be formed of the same width of threads as the screw of the slide-rest at *i*; and if the wheel, W, on the screw, is the

largest, the screw cut will be finer; if, on the other hand, the smallest wheel is fixed on the screw at *W*, it will cut a screw of a coarser thread than the screw *i*. The lathe is provided with wheels of all the different sizes, shewn by the dotted circles *V*, *fig. 7*, any of which may be fixed on at pleasure, either on the screw or the chuck. The screw cut in this manner will have its threads inclined in a contrary direction to the screw of the slide-rest; and if that is a left-handed screw, it will cut a right-handed screw, because the slider-screw revolves in an opposite direction to the spindle. That the lathe may cut screws of either kind, an intermediate cog-wheel is introduced between the two, to cause them to turn the same way. This gives another advantage, *viz.* that any two wheels may be used together; the intermediate wheel communicating motion from one to the other, though they are considerably distant from touching each other. The application of the intermediate wheels is explained in *figs. 8 and 9*, where *r* is a projecting shelf from the standard *a*; upon this a piece of metal, *s*, is fastened by a screw, and a short hollow spindle, *v*, is fitted into it, and fastened by proper screw-collars which admit its rotation; upon the end of this the cog-wheel *W*, which turns the screw of the slide-rest, is fastened by a nut: an arm, *w*, is fitted on the short spindle *v*, so as to have an angular motion round the centre: the arm has a groove in its length, in any part of which the centre pin of the intermediate wheel, *x*, can be fastened; and by these two motions this wheel may be fixed at any joint, so as to connect the wheels of any size. The hollow spindle, *v*, is adapted to receive an arbor or axis *y*, which has a socket in the end adapted to the square, upon

the end of the slide-rest screw *i*: by this method the slide-rest may be set at any part of the lathe bar; when it is required to cut a screw at the end of a long bolt; the arbor *y*, forming the connection between the cog-wheel, *W*, and the screw, for which purpose it slides through the hollow spindle *v*, but is caused to revolve with it, by a feather or fillet projecting from one side; the socket of the hollow spindle may be set and fastened at any required distance from the lathe bar, and fastened by its screw; the slide-rest being set at a correspondent distance from the spindle of the lathe, by moving it upon the bar *P*, will admit a large piece of work, when a screw is required to be cut upon it. *R*, *fig. 7*, is an iron frame, fastened to the lower slider of the slide-rest, to support the screw from bending by the pressure of the tool, when it is long and slender. The frame is shewn in plan in *fig. 10*, where the holes are shewn for the two screws which hold down the frame upon the lower slider.

The methods of holding various pieces of work in the lathes to turn them are endless, and depending in a great measure upon the ingenuity of the workman to adapt them to the particular occasions he meets with. This subject, as well as the figure and manner of holding the tools, will be resumed under the article *TURNING*; an art which, from the facility with which it produces so many beautiful forms, has become a fashionable amusement among gentlemen, who may require many practical instructions, which would be needless to the mechanic regularly educated in the workshop. We shall also describe the method of turning elliptic work, as well as circular.

LATHE.

by M. H. Maudslay.

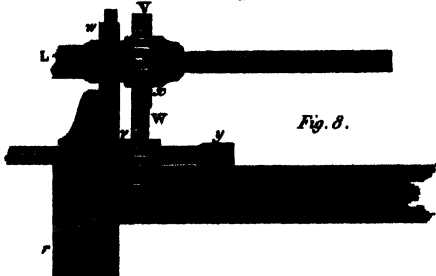
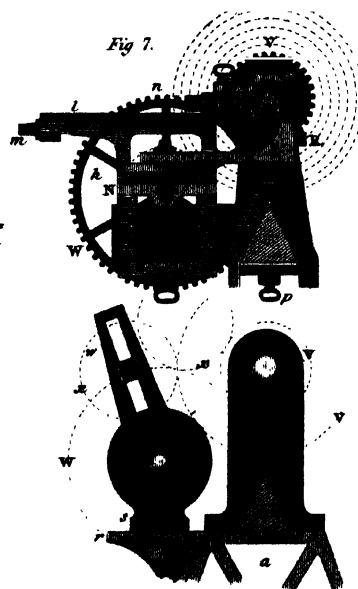
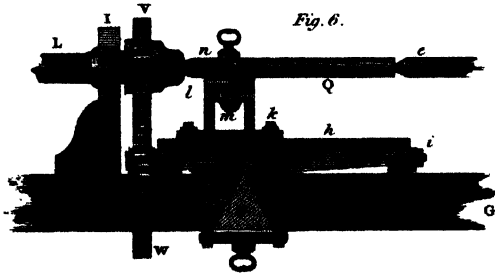
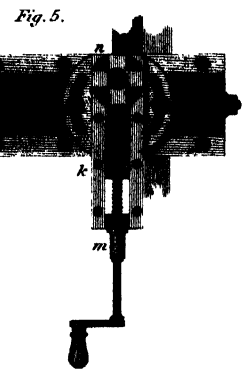
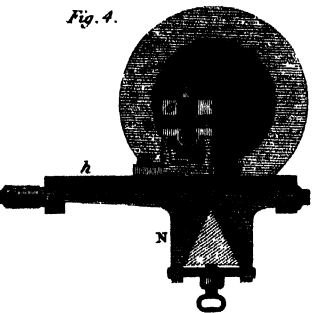
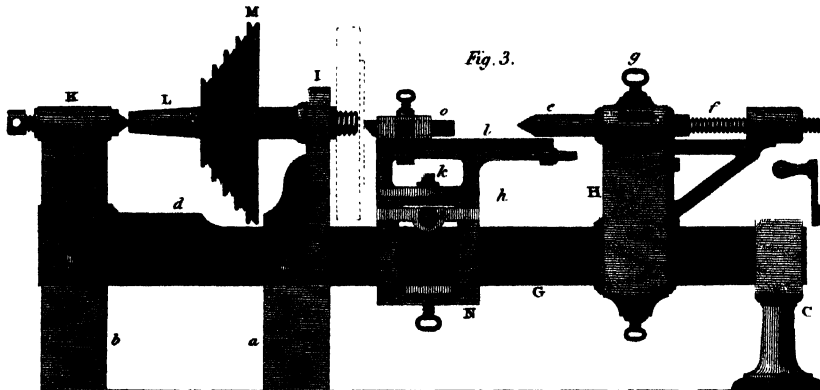
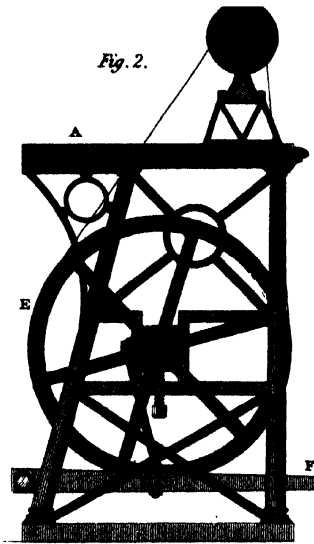
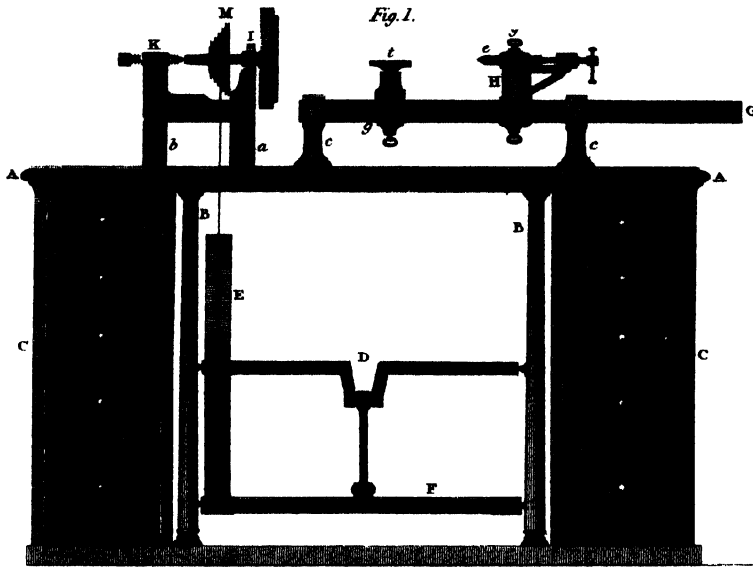
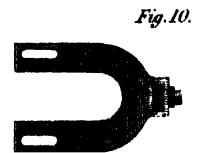


Fig. 9.



Lattin

LATTIN, or LATTEN, a name by which we used to call the plates of iron covered with tin, and now usually called *tin*, of which our mugs, and such other things, are made. The principal part of the work is to prepare the leaves, beat out to a proper thinness, so as that they shall readily receive the tin; for if there be but the smallest particle of dust on them, or only the slightest rust in any part, the tin will never fix there.

This smoothing of the plates is effected by steeping them in acid water, till the surface is a little preyed upon by it, and then they are scowered with sand, which makes them very smooth and fine. By this means a woman cleans more plates in an hour, than the most expert workman can do otherwise in many days. M. Reaumur, to whom the world owes the discovery of this process, mentions several waters, any one of which will succeed, but the Germans themselves use nothing but common water, made eager with rye. This they make a great secret of, but the preparation is very easy. After they have ground the rye grossly, they leave it to ferment in common water for some time; and they are thus sure of a sharp and eager menstruum, excellently fitted for their purpose. With this liquor they fill certain troughs, or tuns, and into these they put several bundles of the plates of iron: and to make the liquor more eager, and to act the better on them, they keep it in stoves, where it has little air, and is kept warm with small charcoal fires.

There are several other ways of making iron rust, as keeping it in a moist cellar, exposing it to the dew, sprinkling it with simple water, or, which is still better, with water in which sal ammoniac has been dissolved, several times a day: and in those countries where the pyrites is common, the vitriolic waters, which partake of it, will do it very well. This water may be prepared at little or no expence, only by heaping up large quantities of the pyrites, and letting it moulder in the air, then putting it into common water, and making a lixivium of it. Whichever method of rusting the plates be used, it is always necessary to scower them with sand as soon as it is done; and when they are thus cleaned, they must be immediately plunged into water, to prevent their rusting again, and they are to be left in this water till the instant in which they are to be tinned, or, in the language of the workmen, *blanched*. The people employed in this part of the operation are called *blanchers*; and the others, who assist at the cleaning of the plates, the *scalers*. The blancher makes as great a secret of his art, as the scaler does of his; and it was with great difficulty that M. Reaumur obtained it. The manner of doing it is this:

They flux the tin in a large iron crucible, which has the figure of an oblong pyramid with four faces, of which two opposite ones are less than the two others. The crucible is heated only from below, its upper part being luted with the furnace all round. The crucible is always deeper than the plates, which are to be tinned, are long; they always put them in downright, and the tin ought to swim over them. To this purpose artificers of different trades prepare plates of different shapes, but M. Reaumur thinks them all exceptionable. But the Germans use no sort of preparation of the iron, to make it receive the tin, more than the keeping it always steeped in water till the time; only when the tin is melted in the crucible, they cover it with a layer of a sort of suet, which is usually two inches thick, and the plate must pass through this before it can come to the melted tin. The first use of this covering is to keep the tin from burning: as if any part should take fire, the suet would soon moisten it, and reduce it to its primitive state again. The blanchers say, this suet is a compounded matter. It is indeed of a black colour, but M. Reaumur supposed that to be only an artifice to make it a secret, and that it is only coloured with soot, or the smoke of a chimney; but he found it true so far, that the common unprepared suet was not sufficient; for after several attempts, there was always something wanting to render the success of the operation certain. The whole secret of blanching, therefore, was found to lie in the preparation of this suet; and this he at length discovered to consist only in the first frying and burning it. This simple operation not only gives it the colour, but puts it into a condition to give the iron a disposition to be tinned, which it does surprisingly.

The melted tin must also have a certain degree of heat, for if it is not hot enough, it will not stick to the iron; and if it is too hot, it will cover it with too thin a coat, and the plates will have several colours, as red, blue, and purple; and upon the whole will have a cast of yellow. To prevent this, by knowing when the fire has a proper degree of heat, they might try with small pieces of iron; but, in general, use teaches them to know the degree, and they put in the iron when the tin is at a different standard of heat, according as they would give it a thicker or thinner coat. Sometimes also they give the plates a double layer, as they would have them very thickly covered. This they do by dipping them into the tin, when very hot, the first time, and when less hot, the second. The tin, which is to give the second coat, must be fresh covered with suet, and that with the common suet, not the prepared. *Philos. Trans. N° 406, p. 634. See TIN.*

Laundry

LAUNDRY, as if *Lavanderie*, Fr. the room in which clothes are washed; or, in a more restricted and appropriate sense, as the term is used in the subsequent article, it denotes the place where clothes are mangled, dried, and ironed. Under this head we shall include the *wash-house*, as it is necessarily connected with the laundry. Washing and getting up linen are employments of great importance in most families, and they have engaged the attention of many ingenious mechanics, who have contrived various washing-machines for the abridgment of labour and expence in this department of domestic economy. Most of the machines hitherto used are objectionable on many accounts, but principally because they operate by *friction*, instead of *pres-*

sure. When the linen is properly prepared for washing, it may be thoroughly cleansed by *pressure* only. Rubbing it with the hands, or by any machine that operates by *friction*, injures it more than the wear it sustains in actual use. Hence it follows that the best method of cleansing foul linen is, first, to prepare it for the operation by soaping it where necessary, and putting it into a soak for at least twelve hours. This will loosen the filth, and decompose the grease and other matter with which it is soiled, and it will then be readily removed by alternately soaking, and squeezing or pressing. The desideratum, therefore, is, to construct a machine that would, by a rotative motion, or an up-and-down stroke, (like pumping) alternately press and saturate the linen with

the suds, and lastly with clear water. The machine that comes nearest to this, of any that has fallen under our notice, is one invented by Mr. Gould.

We shall now describe a wash-house and laundry, constituted upon scientific principles by John Bentley, esq. the present possessor of Highbury House, near London, being the completest of the kind we have met with.

The wash-house is 24 feet long, nine feet broad, and eight feet high. It is furnished with a filtering machine, a cistern for filtered water, two coppers, a copper cullender, a jack with pullies, six washing tubs, a stone sink, a table, a wringing machine, and a pump of hard water.

The floor is rough Yorkshire-stone, laid upon a sharp current. Over two-thirds of the roof is a lead cistern containing 40 hogheads of rain water, supplied from the adjoining buildings. The other third of the roof is conical, surmounted with a cylinder for a steam-vent, which opens and shuts at pleasure. When open, besides emitting the steam, it admits both light and air. The cistern for filtered water holds 200 gallons, and supplies, by pipes and cocks, the copper tubs and sink.

The first copper is fixed so that the top of it is level with the bottom of the cistern, and the bottom of it is level with the top of the other copper, and the tops of the tubs and sink, all which it supplies with hot water. The tubs, coppers, and sink, are supplied with cold water from the cistern. Each of the tubs has a brass plug at bottom, to discharge the foul water. A nine-inch board runs along the front of the tubs and sink on the ground, to prevent the splashing of the water when discharged. Each tub is furnished with a small wooden strainer for soap.

The second copper is for boiling the linen, and has a copper cullender to hold the linen, which is drawn up by the jack and pullies. The jack has a paul and ratchet wheel to keep the cullender suspended over the copper till the water is drained from the linen into the copper, which can then be turned out altogether into the rinsing-tub. By this contrivance, the usual mode of poking the linen out with a stick (which frequently damages it) is avoided. At the bottom of this copper is a large brass cock for discharging the suds when they are done with.

Though the six tubs are supplied with both hot and cold water, there are only six cocks to the whole, one cock supplying two tubs, by means of a screw-joint in the nozzle, which turns at pleasure to either tub. There is also a screw-joint between the key and pipe in each cock, by which means it can at any time be repaired without the assistance of the plumber.

The filtering machine performs its operation by ascent. It has three cocks in one pipe. The uppermost is for regulating the quantity of water to be filtered, which can be varied at pleasure from 50 to 500 gallons in a day. The other is for cleansing the machine when saturated with filth, which is accomplished by only turning the cock, and will, in a few minutes, be as clean as it was at first, the mud, &c. being discharged at the third or middle cock, which also serves to draw unfiltered water when required. Under the cistern is a receptacle for coals, and under the filtering machine a place for pails and mops. Both cisterns have a surplus water-pipe to prevent running over, and in which are also plugs to discharge all the water when needful.

The table hangs to the wall, and may be put up and down at pleasure. It is for sorting and soaping the foul linen, &c.

The laundry adjoining the wash-house is 18 feet square, and 11 feet in height. It has two windows in front. The floor is level, of rubbed Yorkshire-stone, laid upon brick piers,

to keep it perfectly free from damp. It is furnished with one of Baker's large mangles; an ironing-board 12 feet by three feet, with four large drawers for the ironing-cloth, iron-holders, &c. with room for the clothes-baskets underneath; a stove or drying-closet, eight feet by six feet; a furnace for heating the closet and the irons, and a place for coals under the floor, close by the furnace. The closet contains four wooden horses, each with five rails or bars. Each horse runs in and out of the closet upon two small iron wheels, upon an iron rail-way. One horse holds six shirts, or a proportionable quantity of other linen, and the whole will dry off as much and as speedily as six women can wash in succession. It hardens the linen after being ironed, and is also useful for airing feather beds, &c. The linen, whilst drying, is kept free from smoke and dust, and there never can be any steam in the room.

The furnace for heating it is similar to those under coppers or in a hot-house, immediately over which, before it enters the flue to the closet, is an iron oven for heating the irons. The flue is continued round the bottom of the closet, and carried up the end of the building. The top of the horizontal part of the flue is of cast-iron plates; iron being a good, and brick a bad conductor of heat. A few inches above these iron plates, the iron rail-way before mentioned is laid, between which and the flue there is a flooring of wire work. This prevents any accident from the casual falling of linen upon the flues, but does not impede the ascent of warm air. Level with the rail-way, inside the closet, there is an opening 15 inches square, communicating with the external air. The ceiling of the closet is in the form of a hopper, terminating in a funnel of the same diameter (15 inches) as the external air-vent. Both these vents are furnished with a sliding door, which opens and shuts, as required, by pulley cords.

The principle upon which it acts is by heating it to a degree sufficient to excite a strong evaporation from the wet linen, and carrying off the moisture by means of the two vents. During the time of its acquiring this heat, both the vents, and also the horses, are kept closely shut, so that the closet is nearly air-tight. As soon as the proper degree of heat is obtained, both the vents are to be opened, when a strong current of air rushes in at the lowest, carrying up all the vapour from the linen through the upper vent or funnel, when the drying will be very speedily completed. The linen is then removed, a fresh supply put in, and the operation repeated as before, beginning by closely shutting all up.

Besides the dispatch and economy attending this wash-house and laundry, the health and comfort of those employed in them are greatly promoted, by being entirely free from the pernicious effects of damp vapour, and in not being incommoded by any extra heat in hot weather.

Since this article was written, the gentleman above mentioned has made a considerable improvement in the wash-house. He has constructed an apparatus for performing the operation by *steam*. Although it is not yet (December 1811) quite completed, it is sufficiently so to have ascertained by experiment, that every species of *white* linen may be better cleansed this way than it is possible to do it by the hands, or any machine hitherto invented.—We say *white* linen, because the operation proves to be so powerful, that it discharges the colour from all dyed and printed articles that have been tried with it.

At the end of the wash-house a strong iron-boiler is fixed three feet six inches long, one foot eight inches wide, and two feet nine inches deep, with fittings up the same as those for steam-engines, viz. a feeding-pipe with regulator, a

mercury gauge-tube, a three-inch steam-tube, two observation cocks, a safety valve, and a discharging pipe. From the steam-tube, a pipe of $1\frac{1}{2}$ inch bore is continued the whole length of the building; and from this main steam-pipe, others of smaller dimensions, from $\frac{1}{4}$ to $\frac{1}{2}$ inch diameter, are laid on the different steaming vessels. These may be either of wood, tin, or copper; but the latter is certainly best, for the action of steam is so powerful, that it will soon render both wood and tin useless. They must be fitted with a loose grating inside, about two inches from the bottom; a cock at one end, to admit the steam; and another at the other end, quite at the bottom, to discharge the foul water. The process is as follows: Soap the linen where it is very dirty, and put it to soak; then place the linen upon the grating in the steam vessel; cover it up, and turn on the steam. The discharging cock must be occasionally opened, to draw off the condensed steam; and when it is found to come off perfectly clear, which it will do in half an hour, or less, the operation is finished, and the articles will come out perfectly clean, and most beautifully white.

By this simple and easy process, the drudgery of washing is entirely done away; and the saving in time, soap, and other expences, is greater than can well be conceived. The

saving of water in many situations is a matter of consequence; but what is of still more importance, the linen will last double the time it otherwise would do: for as there is neither pressure nor friction, it cannot be injured in this process.

Washing by steam has been practised, but never before by this method. The way it has been done has been by steaming the linen *in the suds*. Hence it is evident that the filth that is forced out of the linen is mixed with the suds, and is again dispersed equally all through the linen; so that repeated changes of soap and water must be had recourse to, before the linen is made thoroughly clean. But by this new process, the linen being put into the steaming vessels, without any other liquor than it retains on being taken out of the soaking tubs, every particle of matter which is dislodged from it instantly subsides to the bottom of the vessel, and never can again come in contact with the linen. Our readers must excuse the prolixity of this article, on account of its great importance and usefulness in domestic economy to every family.

Note.—The boiler above described also heats a hot-house in an adjoining garden, besides boiling a copper, and thus does the work of six fires.

Lavoisier

LAVOISIER, ANTHONY LAWRENCE, in *Biography*, a distinguished chemical philosopher, was born at Paris, on the 13th of August 1743. His father, who was a man of opulence, spared no expence in bestowing upon him the advantages of a liberal education; and he displayed very early proofs of the extent and success of his studies, especially in the circle of the physical sciences. In the year 1764, the French government proposed a prize question, relative to the best method of lighting the streets of a large city. Lavoisier presented a dissertation on the subject, which he discussed upon the most enlarged and philosophical views. This was not only highly approved, and printed at the expence of the Academy of Sciences, but obtained for him the present of a gold medal from the king, which was delivered to him by the president of the Academy, at a public sitting, in April 1766. Two years afterwards, he was admitted a member of that learned body, of which he was constantly one of the most active and useful associates. About the same time, he was occupied in experimental researches on a variety of subjects; such as the analysis of the gypsum found in the

neighbourhood of Paris; the crytallization of salt; the properties of water; and in exploring the phenomena of thunder, and of the aurora borealis: and he distinguished himself by several dissertations on these and other topics, practical and speculative, which appeared in different periodical works. In the Memoirs of the Academy for 1770 were published his observations on the nature of water, and on the experiments which had been supposed to prove the possibility of its conversion into earth. He proved, by a careful repetition of these experiments, that the earthy deposit, left after repeated distillations of water, proceeded solely from an abrasion of the vessels employed. Lavoisier performed several journeys into various parts of France, in company with M. Guettard; in the course of which he collected a store of materials for a lithological and mineralogical history of that kingdom, which he ingeniously arranged in the form of a chart. These materials were the basis of a great work on the revolutions of the globe, and on the formation of the strata of the earth: two interesting sketches of which were

printed in the *Memoirs of the Academy* for the years 1772 and 1787.

In fact, M. Lavoisier devoted his whole time and fortune to the cultivation of the sciences, the boundaries of which he seemed, by such an union of zeal, talent, and wealth, destined to extend. About this period, a new mine of experimental research, which promised the most curious and interesting results, had been opened out by the genius of Dr. Black, and already pursued with much sagacity and industry by Dr. Priestley.—We allude to the discovery of the properties of certain æriform substances, gases, or (as they have been called) factitious airs, which had hitherto escaped the attention of chemical inquirers. M. Lavoisier, struck with the beauty and importance of these discoveries, entered into the same field of research with all the scientific ardour by which he was characterized: and here the advantage of his ample wealth was manifest; for he conducted his experiments upon a large scale, with costly instruments of the most improved construction. The result of this course of experimental inquiry he gave to the world in 1774, in his "*Opuscules Chymiques*," which contained not only a clear and elegant view of all that had hitherto been done, in regard to gaseous or æriform fluids, but also several original experiments, remarkable for their ingenuity and accuracy.

The existence of a gaseous body, in a *fixed* or solid state, in the mild alkalies and alkaline earths, which, when expelled from these substances, assumed an ærial form, and left them in a caustic state, as well as its production during the combustion of fuel, had been demonstrated by Dr. Black; and Bergman had shewn that this air possessed acid properties. Dr. Priestley had also submitted it to various experiments in the year 1767; but no progress had been made in ascertaining the real constituent parts of this acid gas, or fixable air. The honour of this discovery was left for Lavoisier; who, in 1772, by exposing a piece of charcoal, inclosed in a glass vessel, to the action of a lens, discovered that part of the charcoal was consumed, that a diminution of air had taken place in the receiver, and that the residue possessed the properties of the fixable air:—whence he concluded that charcoal was one of the constituent parts of this gas. The combustible nature of the diamond having been already proved by Macquer, d'Arcet, and others, Lavoisier was induced to submit this substance to the same treatment as the charcoal in the former experiment; and he found that precisely the same results took place: whence he inferred, that there existed a great analogy between charcoal and diamond. Both these conclusions have been amply confirmed by subsequent experiments; they were in every respect important; and seem, together with the facts previously known, of the production of acids by the combustion of sulphur and phosphorus, to have given the first hint to Lavoisier of his subsequent general theory of the formation of acids.

Lavoisier now turned his experimental researches to the subject of the *calcination* (as it was then termed, from its apparent similarity to the process of making *lime*) of metals. It had already been shewn by Rey and Homberg, that metals acquire an augmentation of weight during calcination. This additional weight was attributed by the latter to the fixation of heat and light; but was supposed by the former to proceed from the fixation of a part of the air. M. Lavoisier published the result of his investigation of this curious subject in 1774, in a memoir on the calcination of tin in close vessels, in which he demonstrated the following very important facts. He shewed, 1, that a given quantity of air was requisite for the calcination of a given quantity of tin; 2, that a part of the air is absorbed during this pro-

cess, by which not only the bulk, but the weight of the air is diminished; 3, that the weight of the tin is increased during the same process; and, 4, that the weight acquired by the tin is exactly equal to that which is lost by the air.

Thus by a few simple, accurate, and well-chosen experiments, Lavoisier had apparently arrived at the legitimate inference, that during the process of the formation of acids, whether with carbonaceous matter, sulphur, or phosphorus, and also during that of the calcination of metals, an absorption and fixation of air take place, and thus he gained a glimpse of principles, in the view of which his singular sagacity in devising experiments, and his accuracy in executing them, would in all probability have alone conducted him to those brilliant results, to which the active genius of Dr. Priestley so materially contributed. The synthetic proofs only of this union of air with the base had been as yet ascertained: but Dr. Priestley first furnished the analytic proof, by disengaging the combination; a discovery which at once advanced the nascent theory of Lavoisier, and, in his hands, became the source of more than one important conclusion. In August 1774, Dr. Priestley discovered, that by heating certain metallic calces, especially the calcined mercury, (the precipitate *per se*, as it was then called,) a quantity of air was separated, while the mercury resumed its metallic form; and this air, which he found was much purer than that of the atmosphere, he called, from the theory of the time, *dephlogisticated* air. The succeeding winter he spent at Paris, and communicated to Lavoisier, and the other philosophers there, his recent discovery: and the importance of this intelligence to the views of Lavoisier was manifest in a memoir published by him in the following year, 1775, on the nature of the principle which combines with metals during their calcination. In this paper he shewed, in conformity with the experiments of Dr. Priestley, that the mercurial precipitate *per se*, by being heated in a retort, gives out a highly respirable air, (since called *oxygen*), and is itself reduced to the metallic state; that combustible bodies burn in this air with increased brilliancy; and that the same mercurial calx, if heated with charcoal, gives out not the pure air, but fixed air:—whence he concluded that fixed air is composed of charcoal and the pure air. It has, therefore, since been called *carbonic acid*.

A second very important consequence of Dr. Priestley's discovery of the pure or vital air, was the analysis of the air of the atmosphere: which was accomplished by Lavoisier in the following manner. He included some mercury in a close vessel, together with a known quantity of atmospheric air, and kept it for some days in a boiling state: by degrees a small quantity of the red calx was formed upon the surface of the metal; and when this ceased to be produced, the contents of the vessel were examined. The air was found to be diminished both in bulk and weight, and to have been rendered altogether incapable of supporting combustion or animal life: part of the mercury was found converted into the red calx, or precipitate *per se*; and, which was extremely satisfactory, the united weight of the mercury and the precipitate exceeded the weight of the original mercury, by precisely the same amount as the air had lost. To complete the demonstration, the precipitate was then heated, according to Dr. Priestley's first experiment, and decomposed into fluid mercury and an air, which had all the properties of vital air; and this air, when mixed with the unrespirable residue of the original air of the receiver, composed an elastic fluid possessing the same properties as atmospheric air. The vital air was afterwards made the subject of various experiments in respect to the calcination of metals, to the combustion and conversion of sulphur and phosphorus into

acids, &c. in which processes it was found to be the chief agent. Hence it was named by Lavoisier *oxygen* (or generator of acids), and the unrespirable residue of the atmosphere was called *azot*, (*i. e.* incapable of supporting life.)

The new theory thus acquired farther support and consistency: oxygen appeared to be one of the most active and important agents of chemistry and of nature; combustion, acidification, and calcination, (or, as it was now called, *oxydation*, the calces being also termed *oxyds*, *i. e.* something approaching to, or resembling acids,) were proved to be processes strikingly analogous to each other; all according in these points, that they produced a decomposition of the atmospheric air, and a fixation of the oxygenous portion in the substance acidified or calcined.

Time alone seemed now requisite to establish these doctrines, by exemplifying them in other departments of chemical research. In the year 1777, six memoirs were communicated to the Academy of Sciences by Lavoisier, in which his former experiments were confirmed, and new advances were made to a considerable extent. Our countrymen, Black and Crawford, in their researches respecting latent heat, and the different capacities of bodies under different circumstances, had laid a solid foundation, on which the doctrines of combustion, resulting from the foregoing experiments, might be perfected, and the cause of the light and heat connected with it might be explained. The first mentioned philosopher, Dr. Black, had shewn, that a solid, when it is made to assume a liquid form, and a liquid, when it assumes the form of vapour, absorbs or combines with, and renders latent, a large portion of heat, which is again parted with, becomes free and cognizable by the sense of feeling, and by the thermometer, when the vapour is again condensed into a liquid, and the liquid becomes solid. In like manner, it was now said by Lavoisier, during the process of combustion, the oxygen, which was previously in a gaseous state, is suddenly combined with the substance burnt into a liquid or solid. Hence all the latent heat, which was essential to its gaseous state, being instantaneously liberated in large quantity, produces flame, which is nothing more than very condensed free heat. About the same time, the analogy of the operation and necessity of oxygen in the function of respiration, with the preceding hypothesis of combustion, was pointed out by Lavoisier. In the process of respiration, it was found that, although atmospheric air is inhaled, carbonic acid and azot are expired. This animal operation, said Lavoisier, is a species of slow combustion: the oxygen of the air unites with the superfluous carbon of the venous blood, and produces carbonic acid, while the latent or combined *caloric* (the matter of heat) is set free, and thus supplies the animal heat. Ingenious and beautiful, however, as this extension of the analogy appeared, the subject of animal temperature is still under many obscurities and difficulties.

The phenomena of chemistry, however, were now explicable upon principles more simple, consistent, and satisfactory than by the aid of any former theory; and the Lavoisierian doctrines were every where gaining ground. But there yet remained a formidable objection to them, which was derived from a circumstance attending the solution of metals in acids; to wit, the production of a considerable quantity of inflammable air. If sulphuric acid (formerly called vitriolic acid, or oil of vitriol) consists only of sulphur and oxygen, it was said, and bar iron is nothing more than this metal in a simple state, how does it happen, that when these two substances, with a little water, come in contact, they should produce a large quantity of inflammable air during their re-action? This objection was unanswerable, and appeared to be fatal

to the whole theory: but it was most opportunely converted into an argument in its favour, by the great discovery of the decomposition of water, made by Mr. Cavendish; who resolved that element, as it was formerly esteemed, into oxygen and inflammable air. The latter has since, therefore, been called *hydrogen*, or generator of water. This experiment was repeated with full success by Lavoisier and his associates in 1783; and the discovery was farther established by a successful experiment of the same chemists, carried on upon a grand scale, in which, by combining the oxygen with hydrogen, they produced water, and thus adding synthesis to analysis, brought the fact to demonstration.

This new view of chemical phenomena, together with the immense accession of new compounds and substances, which the labours of modern experimentalists had brought to light, appeared to demand a correspondent alteration in the nomenclature. Accordingly, a committee of some of the ablest of the French chemists, of whom Lavoisier was the most conspicuous, undertook the arduous task, and produced a regular system of nomenclature, derived from the Greek language, which, although far from being faultless, and notwithstanding much opposition with which it was at first treated, has become the universal language of chemical science, and has been adopted even in pharmacy and medicine. His work, entitled "*Elémens de Chymie*," which was published in 1789, was a model of scientific composition.

We have hitherto viewed M. Lavoisier principally as a chemical philosopher, in which character he has founded his great claims to the respect and admiration of posterity. But the other arts and sciences are indebted to him for considerable services which he rendered them, both in a public and private capacity. In France, more than in any other country, men of science have been consulted in matters of public concern; and the reputation of Lavoisier caused him to be applied to, in 1776, to superintend the manufacture of gunpowder, by the enlightened minister Thurgot. By the application of his chemical knowledge to this manufacture, he was enabled to increase the explosive force of the powder by one fourth; and while he suppressed the troublesome regulations for the collection of its materials from private houses, previously adopted, he quintupled the produce. The Academy of Sciences received many services from his hands. In addition to the communication of forty papers, relative to many of the most important subjects of philosophical chemistry, which were printed in the twenty volumes of *Memoirs*, from 1772 to 1793, he most actively promoted all its useful plans and researches, being a member of its board of consultation, and, when appointed to the office of treasurer, he introduced order into its accounts, and economy into its expenditure. When the new system of measures was proposed, he contributed some new and accurate experiments on the expansion of metals. The national convention consulted him with advantage concerning the best method of manufacturing assignats, and of securing them against forgery. Agriculture early engaged his attention, and he allotted a considerable tract of land on his estate in the Vendôme, for the purpose of experimental farming. The committee of the constituent assembly of 1791, appointed to form an improved system of taxation, claimed the assistance of his extensive knowledge; and he drew up, for their information, an extract of a large work on the different productions of the country and their consumption, for which he had been long collecting materials. This was printed by order of the assembly, under the title of "*Richesses Territoriales de la France*," and was esteemed the most valuable memoir on the subject. In the same year, he was appointed one of the commissioners of the national treasury; and he introduced

into that department such order and regularity, that the proportion between the income and the expenditure, in all the branches of government, could be seen at a single view every evening. This spirit of systematic and lucid arrangement was, indeed, the quality by which he was peculiarly distinguished, and its happy influence appeared in every subject which occupied his attention.

The private life of this distinguished person was equally estimable with his public and philosophical character. He was extremely liberal in his patronage of the arts, and encouraged young men of talents in the pursuit of science. His house became a vast laboratory, where philosophical experiments were incessantly carrying on, and where he held conversaciones twice a week, at which all the votaries of learning and science, foreigners as well as Frenchmen, assembled. In his manners M. Lavoisier was mild, affable, and obliging; a faithful friend and husband, a kind relation, and charitable to the poor upon his estates; in a word equally claiming esteem for his moral qualities, as for those of his understanding.

The time was arrived, however, when distinction even by his talents and worth was so far from securing public respect, amid the tumults of the revolution, that it became a source of danger, and, when joined with wealth, was almost certainly fatal. All those especially, who had held any situation under the old administration, particularly in the financial departments, were sacrificed during the murderous reign of Robespierre, to the popular odium. Lavoisier was seized and thrown into prison, upon some charges fabricated against himself and twenty-seven other farmers-general. During his confinement he foresaw that he should be stripped of all his property; but consoled himself with the expectation that he would be able to maintain himself by the practice of pharmacy. But a more severe fate awaited him: he was capi-

tally condemned, and dragged to the guillotine, on the 8th of May, 1794.

The name of Lavoisier will always be ranked among the most illustrious chemists of the present age, when it is considered what an extensive and beneficial influence his labours have had over the whole science. It has been said, indeed, that if he be estimated on the score of his actual discoveries, not only Scheele and Priestley, and Cavendish, but many more, will stand before him. But he possessed in a high degree that rare talent of discernment, by which he detected analogies, which others overlooked, even in their own discoveries, and a sagacity in devising and an accuracy in completing his experiments, for the purpose of elucidating every suggestion which he thus acquired, such as few philosophers have possessed. No one who did so much, probably ever made so few unsuccessful or random experiments. It was the singular perspicuity, simplicity and order to which he reduced the phenomena of chemistry, that claimed for his theory the general reception which it met with, and occasioned the abandonment of those doctrines which prejudice and habit conspired to support. Subsequent discoveries, however, and more especially those numerous facts which the genius of Mr. Davy has lately brought to light, through the medium of that most powerful agent of decomposition, galvanism, have rendered several modifications of the Lavoisierian theory necessary, and bid fair to produce a more general revolution in the language and doctrines of chemistry.

M. Lavoisier married, in 1771, the daughter of a farmer-general, a lady of pleasing manners and considerable talents, who partook of her husband's zeal for philosophical inquiry, and cultivated chemistry with much success. She engraved with her own hand the copper plates for his last work. M^{rs}. Lavoisier has since given her hand to another eminent philosopher, count Rumford. Gen. Biog. Hutchins^{on}'s Biog. Med.

Lead

LEAD, in *Mineralogy*, *Plumbum*, Lat.; *Plomb*, Fr.; *Bley*, Germ.; *Saturnus*, Alchem. The colour of lead is of a blueish-white; when tarnished, it becomes yellowish-white, then blueish, and at last blueish-black. Lustre, when untarnished, 3; hardness, 5; and specific gravity somewhere between 11 and 12. According to Briffon, it was 11.352; and a specimen tried by Gellert, which was found at Freyburg, was estimated at 11.445. Next to gold, platina, and mercury, it is the heaviest metal, being upwards of eleven times heavier than an equal bulk of water. (See *Specific Gravity*.) The heaviest is reckoned the best. It stains paper and the fingers. Next to tin, it is the most fusible of all the metals. It is soluble in most of the acids, though more readily so in the nitrous diluted than the others. By exposure to the moist atmosphere, it rusts or oxyds. It is malleable and unelastic, and its oxyd is easily fusible into a transparent yellow glass. Having given this general description, we shall now consider the several combinations under which it is found in nature.

Ores of Lead.

Sp. 1. *Lead Glance*. *Bleiglanz*. This species contains two subspecies: (1) *Common lead-glance*, the colour of which is of a lead-grey, of different kinds of intensity; in some varieties it inclines to a blackish cast. The lead-grey frequently contains the greatest proportion of silver. It sometimes presents superficially an iridescent tarnish. It occurs massive, disseminated, in membranes, in angular pieces, and in grains; sometimes it is met with reticulated, specular, corroded, and amorphous; seldom cylindrical, but often

crystallized. The crystalline form exhibits several varieties: 1, in the shape of a cube, in which the planes are either straight or spherical convex; 2, the cube having angles more or less deeply truncated; 3, the cube having its edges and angles truncated at the same time, but of these the latter the most deeply; 4, octahedron, either perfect or truncated on all its angles; 5, octahedron having its angles and edges truncated at the same time; 6, rectangular four-sided prisms, acuminate on both extremities by four planes, which are set on lateral edges; 7, six-sided prisms, acuminate by four planes; 8, three-sided tables, in which the terminal planes are bevelled. The crystals are usually small, or at most middle-sized, either grouped on one another, implanted, or solitary. The planes of the crystals are sometimes smooth, sometimes drusy, and sometimes rough. Internally it alternates from specular splendid to glitening; on the external surface it is less bright, but its lustre is metallic. Its fracture is more or less perfect foliated, and its fragments are cubical. In mass it is often composed of granular, and rarely of lamellar distinct concretions, which are much grown together, and whose fracture has a radiated aspect. It is soft, perfectly sectile, easily frangible, and the specific gravity is from 6.2 to 7.8 nearly. Before the blowpipe it flies to pieces, and emits a sulphureous odour. It is easily fusible, and may be readily reduced on coal before the blowpipe. When it is alternately heated and cooled, it at length disappears entirely; and if it contain silver, a globule of that metal remains behind. According to Vauquelin, lead-glance contains the following ingredients:

	From Kirchwald, in Deux Ponts.	Kampfsstein.	Ecklerberg.	Kantenbach.	Cologne.
Lead	54	69	68.69	64	63.1
Sulphur	8	16	16.18	18	12.
Carbonated lime and silex	38	15	16.13	18	19.67
Oxyd of iron	0	0	0	0	3.33
	100	100	101	100	98.1

Dr. Thomson gives the following as the result of his experiments:

Lead	85.13
Sulphur	13.02
Oxyd of iron	0.5
	98.65
Loss	1.35
	100

Hence, as is evident from the above tables, the proportion of lead varies from 54 to rather more than 85 *per cent*. The proportion of silver varies considerably also; and it appears to have an effect on the external aspect of the varieties. It sometimes also contains a small portion of iron; and gold has even been found in lead-glance. It is, next to pyrites, the most common of metallic ores, and is found in beds and veins in primitive, transition, and secondary mountains. It occurs almost always with blende and calamine, with which it appears to have a strong geognostic affinity. It is frequently

accompanied with silver ores, and sometimes with copper ores. To mention all the places in which it is found, would be to mention almost all the known mineral districts in the world. It is very abundant in Germany, and also in many places in our own country. The lead-mines in Britain are situated in Cornwall, Devonshire, and Somersetshire, in Derbyshire, Durham, Lancashire, Cumberland, and Westmoreland; in Shropshire, in Flintshire, Denbighshire, Merionethshire, and Montgomeryshire; at the lead-hills in Scotland, on the borders of Dumfriesshire and Lanarkshire, in Ayrshire, and at Strontian in Argyleshire. Lead-glance is also found at Konigsberg in Norway; in various parts of Lapland, and in Denmark and Sweden; in several districts of Saxony, Hungary, Transylvania; in France, Italy, and Spain. Most of the lead of commerce is procured from this ore: it is also used without farther preparation in the potteries for coarse work, and also in the smelting of silver ores. Lead-glance is now generally used as a scientific name, in preference to the less significant but common one *galena*, on account of its lustre, which forms a striking feature in the external aspect of this mineral. (2) The second subspecies

is *compact lead-glance*. The colour of this is very similar to that of the common lead-glance. It occurs in mafs, diffe-minated, and specular. The latter is externally smooth, fhining, and fplendent; internally it is glimmering, and its luftre is metallic. Its fracture is even. It acquires a polifh by friction; its ftreak is fhining, almofl fplendent; not fo eafily frangible as the preceding fubfpecies; but agrees with it in the other characters. Its fpecific gravity is about 7.4. It occurs in veins, and is ufually accompanied with the common lead-glance. When the two fubfpecies occur together, the compact always forms the fides of the vein, and this probably owing to its having been in a lefs perfect ftate of folution. It is accompanied with black blende, common iron pyrites, copper pyrites, quartz, and heavy fpar. It is found in the lead-hills in Lanarkfhire, and in Derbyfhire; in divers parts of Germany, and in the valley of Chamouni in Switzerland.

Sp. 2. *Blue lead ore*. *Blaubl-yerz*, Wern. *Mine de plomb bleu*, Broch. The colour of this fpecies is intermediate between dark indigo blue and lead-grey. It occurs mafive, and cryftallized in perfect fix-fided prifms, which are ufually fmall, low, fometimes bulging, with a furface rough and dull. Internally it is feebly glimmering, and its luftre is metallic. The fracture is even, paffing into the fine-grained uneven and flat conchoidal. Its fragments are indeterminately angular. It is opaque, gives a fhining metallic ftreak, is foft, feftile, and eafily frangible. Its fpecific gravity is 5.46. It eafily melts before the blowpipe, burns with a weak blue flame, emits a ftrong fulphureous vapour, and is reduced to pure lead. It is conjectured to be a compound of lead, oxyd of lead, and fulphur; and is fuppofed by Werner to be intermediate between lead-glance and black lead ore. Klaproth difcovered in it phofphoric acid. It occurs in veins, accompanied with black lead ore, white lead ore, malachite, radiated copper azure quartz, fluor-fpar, and heavy fpar. It is not often to be met with, and has hitherto been found only at Zfchoppau in Saxony, at Schemnitz in Hungary, and Brittany in France.

Sp. 3. *Brown lead ore*. *Braun bleyerz*, Wern. *La mine de plomb brun*, Broch. Its colour is hair-brown, of different degrees of intensity, fometimes very pale, approaching to grey, and fometimes it paffes into a clove-brown. It occurs mafive, and is cryftallized in fix-fided prifms. The furface of the cryftals is blackifh and rough. Internally it is gliftening, and its luftre is refinous. The fracture is fmall and fine-grained uneven, and fometimes paffes into fplintery. It is foft, not very brittle, but eafily frangible. Its fpecific gravity between 6.60 and 6.98. It melts eafily before the blowpipe, without being reduced; and, during the cooling, fhoots into acicular cryftals. It does not effervefce with acids. According to Klaproth, a fpecimen from Brittany contained,

Oxyd of lead	-	-	78.58
Phofphoric acid	-	-	19.73
Muriatic acid	-	-	1.65
			99.96
Lofs			4
			100

It is found at Mies in Bohemia; alfo in parts of Hungary, Saxony, and Lower Brittany. In Bohemia it is ufually found accompanied with lead-glance, white, black, and green lead ores, copper pyrites, blende, quartz, heavy fpar, &c. It occurs in veins.

Sp. 4. *Black lead ore*. *Schwarz bleyerz*, Wern. *La mine de plomb-noire*, Broch. The colour of this fpecies is greyifh-black, of different degrees of intensity. It occurs in mafs, diffe-minated or cellular, or cryftallized in fix-fided prifms. It is externally fplendent, and internally only fhining. Fracture fmall-grained uneven, which fometimes paffes into imperfect conchoidal and fplintery. Fragments indeterminately angular; ftreak greyifh white; rather brittle; eafily frangible. Specific gravity about 5.8. Before the blowpipe it decrepitates, and is quickly reduced to a metallic globule. According to Lampadius it confifts of,

Lead	-	-	-	72
Oxygen	-	-	-	7
Carbonic acid	-	-	-	18
Carbon	-	-	-	2

Lofs				99
				1
				100

It occurs in veins, and is almofl always accompanied with white lead ore and lead-glance, and ufually in the upper part of veins, and in new lead-glance formations. It very frequently encruffs lead-glance, and is covered with white lead ore, and fometimes by green lead ore. It is found in the lead-hills of Scotland; in different parts of Bohemia, Saxony, Salzburg, Lower Brittany, and in Siberia. Previously to the analysis of Lampadius, Haüy fuppofed it was a phofphate of lead; and Werner fufpected that it was a compound of lead, carbonic, and fulphuric acids.

Sp. 5. *White lead ore*. *Wies-bleyerz*, Wern. *Mine de plomb blanche*, Broch. This is a carbonate of lead: its colour is a greyifh or yellowifh-white, with very many different fhades. It occurs mafive, diffe-minated, but moft frequently in a cryftallized ftate. The chief varieties are, 1, the cuneiform octahedron; 2, the pyramidal dodecahedron; 3, the preceding, with a fix-fided prifm interpoled between the pyramids; 4, the fame as variety 3, with fummits of the terminal pyramids replaced by a fix-fided plane; 5, a fix-fided prifm, with fummits compofed of four planes; 6, the fame, with fummits compofed of fix planes. The cryftals are ufually fmall. Externally, it is fpecular fplendent, feldom gliftening: internally, it alternates from highly fplendent to gliftening, and its luftre is adamantine, inclining fometimes to femi-metallic, and fometimes to refinous. The fracture is commonly fmall conchoidal, but it frequently paffes into fine-grained uneven, and even into fine fplintery. Fragments indeterminately angular. It alternates from tranf-lucent to transparent, and is duplicating. It is foft, brittle, and eafily frangible. Its fpecific gravity is from 6 to 7.24, according to the different fpecimens that have been analyzed. Before the blowpipe it flies to pieces, becomes red, yellow, and lafly melts into a globule of metallic lead. It makes a ftrong effervescence with acids. Its furface becomes black, when expofed to the vapour of fulphuret of ammonia. Its conftituent parts are as follow:

From Siberia, analyfed by Macquer.				From the Lead-hills in Scotland, analyfed by Klaproth.			
Lead	-	-	67	Lead	-	-	77
Carbonic acid	-	-	24	Carbonic acid	-	-	16
Oxygen	-	-	6	Oxygen	-	-	5
Water	-	-	3	Water	-	-	2
100				100			

But according to two other able chemists, they are as follow :

From Zellerfeld.	First Analysis.	Second Analysis	From Ildersdorf.	First Analysis.	Second Analysis.
Lead - -	81.2	80.25	Lead - -	74.0	77.50
Carbonic acid - -	16.	16.0	Carbonic acid - -	15.0	15.0
Oxyd of iron - -	0.3	0.18	Oxyd of iron - -	0.25	1.25
Alumine - -	0.0	0.75	Alumine - -	1.0	0.0
Lime - -	0.9	0.50	Lime - -	1.0	0.0
			Silicia - -	0.25	0.50
			Water - -	4.0	0.0
Loss - -	98.4	97.68		95.50	94.25
	1.6	2.22	Loss	4.5	5.75
	100	100		100	100

It is almost always accompanied with lead-glance, and occurs in a kind of repository. It occurs in veins that traverse transition rocks; though it is found with different minerals, in different parts of the world. It is not a rare mineral, but is seldom found in sufficient quantities to make it worth while to separate it from the adhering spar, for the purpose of smelting. The finest specimens of this ore that are found in Britain come from the mines of Derbyshire, the Lead-hills in Scotland, and Minera in Denbighshire. It is also found on many parts of the continent.

Sp. 6. *Green lead-ore.* *Grün Bleyerz*, Wern. *La mine de plomb verte*, Broch. The colour of this species is grass-green, which passes on through the several shades into greenish-white. The olive and pistachio-green colours are the most common. It occurs massive, sometimes reniform, but most commonly crystallized. The varieties are, 1. Six-sided prisms, having sometimes the lateral and terminal edges truncated. 2. When the lateral edges of the prism converge towards their extremities, an acute, double, six-sided pyramid is formed. The crystals are small; externally smooth and shining; internally glistening; the lustre is resinous. Fracture small-grained, uneven. Fragments angular and blunt-edged: it is soft, rather brittle, and easily frangible. Specific gravity 6.27 to 6.94. Before the blowpipe it does not fly to pieces: it becomes white and melts easily into a greyish-globule, but without being reduced even with charcoal. It dissolves in acids without effervescence. Its constituent parts are, according to

Fourcroy		
Oxyd of lead -	-	79
Phosphoric acid -	-	18
Oxyd of iron -	-	1
Water -	-	2
		100

Vauquelin		
Lead - -	-	45.18
Phosphoric acid -	-	18.17
Oxygen - -	-	4.05
Silica - -	-	32.
		99.40
Loss - -	-	60
		100

Green lead-ore is, when of a pale colour, apt to be confounded with the preceding species; but it may be distin-

guished by the following characteristics: 1. The fracture in this species is fine-grained, uneven, but in white lead-ore it is more or less conchoidal. 2. Its lustre is resinous. 3. It is harder than white lead-ore. 4. It is of a greater specific gravity. 5. Its crystals are often aggregated: and 6. Its prisms are generally shorter than those of white lead-ore.

Sp. 7. *Red lead ore.* *Roth Bleyerz*, Werner. *Red lead-spar*, Kirwan. *La mine de plomb rouge*, Brochant. The colour of this mineral is of a hyacinth-red, sometimes inclining to aurora, or morning red. It occurs most commonly crystallized in broad four-sided prisms, and but rarely massive, disseminated, or in membranes. The crystals are middle-sized: the surface of the crystals is usually smooth, sometimes longitudinally streaked. Both externally and internally it is splendid, and its lustre is intermediate between adamantine and resinous. The fracture is foliated, and the fragments indeterminately angular. It sometimes inclines to transparency. It is soft, and in the intermediate state between very brittle and sectile: easily frangible, and its specific gravity is somewhere between 5.6 and 6.0. It melts before the blowpipe into a blackish scoria, and may be partly reduced with borax. Specimens have been analysed by

Vauquelin		Thenard	
Lead - -	57.10	Oxyd of lead	64
Oxygen - -	6.86	Chromic acid	36
Chromic acid -	36.04		
	100		100

This mineral occurs in veins in gneiss and mica slate, where it is accompanied with lead-glance, green lead-ore, iron pyrites, brown iron-stone, native gold and quartz. It is found in Siberia; at Annaberg, in Austria; and at Upper Faucigny, in Savoy. It is much used as a pigment, on account of its beautiful colour, its durability in the atmosphere, and its mixing readily with oil.

Sp. 8. *Yellow lead-ore.* *Gelbes Bleyerz*, Werner. *Yellow lead-spar*, Kirwan and Hatchett. *Plomb molybdaté*, Haüy. *La mine de plomb jaune*, Brochant. In this species, which has long been known to mineralogists, the lead is mineralized by a particular metallic acid, called the molybdic acid. It occurs sometimes massive, more commonly crystallized in small crystals; the forms of which are rectangular tables of four sides, or of eight sides, bevelled; the cube, octahedron, equiangular eight-sided table, and double eight-sided pyramid. The tables are usually broad and thin, and alternate from small to very small, but are seldom middle-sized.

They are sometimes united, frequently intersect one another, and form thus the cellular external shape. Its colour is wax-yellow, and its lustre distinctly waxy: it is translucent, soft, and easily frangible. Its specific gravity is rather more than 5. It decrepitates before the blowpipe, then melts into a globule of a grey colour, in which are disseminated particles of metallic lead. It gives a blueish-white colour to borax: it occasionally produces a glass, which is greenish-blue, and sometimes deep blue. Its constituent parts are, according to

Klaproth's Analysis		Hatchett's Analysis	
Oxyd of lead	64.42	Oxyd of lead	58.40
Oxyd of molybdena	34.25	Molybdic acid	38.0
	<hr/>	Oxyd of iron	2.08
	98.67	Silica	0.28
Lofs	1.33		<hr/>
			98.76
		Lofs	1.24
			<hr/>
			100

Macquart's Analysis

Lead	-	58.75
Molybdena	-	28.0
Oxygen	-	4.76
Carbonate of lime	-	4.50
Silica	-	4.

100.01

It occurs on compact lime-stone which is much traversed by veins of calc-spar, and is accompanied with molybdena and yellow lead-earth; sometimes, also, with lead-glance, white, black, and green lead-ore, calamine, blende, the calc and fluor spars. It is found principally in Carinthia; though it is met with at Annaberg, in Austria; also in Hungary, Silesia, Saxony, Burgundy, in France, and other places.

Sp. 9. *Lead vitriol, or sulphate of lead.* *Bléi vitriol*, Werner. *Native vitriol of lead*, Kirw. *Plomb sulphaté*, Haüy. *Le vitriol de plomb natif*, Broch. The colour of this mineral is yellowish grey, passing to the greyish-white; the lighter varieties incline much to white. It occurs only in crystals, the form of which is rectangular octahedrons with obtuse pyramids. The pyramids are often variously truncated. Externally it is shining; internally it is splendid. The fracture is compact; it is more or less transparent: is softish, rather brittle, and its specific gravity is about 6.3. It is easily reduced, when exposed to the flame of the blowpipe; and is insoluble in the nitrous acid. Specimens have been analysed by Klaproth; the constituent parts are as follow: viz. of that from

	Anglesea	Wanlock-head
Oxyd of lead	71	70.50
Sulphuric acid	24.8	25.75
Water of crystallization	2	2.25
Oxyd of iron	1	<hr/>
	98.8	98.50
Lofs	1.2	1.5
		<hr/>
		100.

It occurs in lead-glance veins at Wanlock-head, and in brown iron-stone in the island of Anglesea. It has also been found in lead-glance veins in Andalusia in Spain.

Sp. 10. *Lead-earth. Bleyerde*, Wern. is divided into two

sub-species; 1, the coherent; and 2, the friable. 1. The coherent, or indurated, named *Verhärtete bleierde* by Werner, and *Le plomb endurci* by Brochant, is of a yellowish or greenish-grey colour. It is sometimes of a smoky-grey, and sometimes of a light brownish-red. It occurs in mass. Internally it is glimmering, passing into glittering, and its lustre is resinous. Its fracture is fine-grained, uneven, passing into fine splintery and earthy, also into flat conchoidal. It is opaque, or, at most, slightly translucent on the edges. It gives a brownish streak, is soft, passing into friable, not brittle, but inclining to sectile, and heavy. It is easily reduced before the blowpipe, effervesces with acids, and becomes black with sulphuret of ammonia. It does not appear to have been hitherto analysed, but is supposed to be in intimate combination with white lead ore, alumine, and lime. It occurs with the other ores of lead, and is usually accompanied by iron pyrites, malachite, and quartz. The yellow varieties are found in Derbyshire, in some parts of Germany, at La Croix in France, and at Nertschinsk in Siberia. The other varieties are to be met with at Wanlock-head, in the Lead-hills in Scotland, in Saxony, Silesia, Poland, &c. 2. *Friable lead-earth. Zerreibliche bleierde*, Werner. *Le plomb terreux friable*, Brochant, is of a yellowish-grey, approaching to sulphur-yellow. It occurs friable; sometimes massive and disseminated. It is composed of dull dusty particles, which are more or less cohering, and soil a little. It has a rough feel, and is heavy. It occurs on the surface, or in the hollows of other minerals, and is usually accompanied with lead-glance, and other ores of lead, and is found at Wanlock-head, and the Lead-hills of Scotland, at Zellerfeld in the Hartz, near Freyberg, in the electorate of Saxony, in the mountains of Cracow, Poland, at La Croix in France, and at Berefowskoi in Siberia. It is in some instances observed passing into solid lead-earth, and is probably formed by the decomposition of lead-glance, as it is frequently met with as a crust upon it.

Sp. 11. Another species is denominated a triple sulphuret of lead. Its colour is dark-grey inclining to black. It occurs crystallized. Its primitive figure is a rectangular tetrahedral prism, besides which it presents the following varieties. 1. The primitive crystal with solid angles replaced by triangular planes. 2. The same with lateral edges replaced by rectangular planes. 3. The same terminated by a very low and deeply truncated tetrahedral pyramid. 4. Four prisms with deeply truncated dihedral summits joined together at their bases, forming a rectangular cross. The crystals are large and middle-sized, with a splendid metallic lustre both externally and internally. Its fracture is coarse-grained and uneven. It is brittle and easily frangible. It leaves a faint black trace when rubbed on paper. Specific gravity 5.8 nearly. When suddenly heated before the blowpipe it crackles and splits; but if gradually heated it melts, and on cooling forms a globule of a dull metallic grey colour. According to an analysis made by Mr. Hatchett, it consists of

Sulphur	-	-	17
Lead	-	-	42.62
Antimony	-	-	24.23
Copper	-	-	12.8
Iron	-	-	1.2
			<hr/>
Lofs	-	-	97.85
			2.15
			<hr/>
			100

It is found in a mine at Huel-Boys in Cornwall.

The existence of native lead, which has been maintained by several mineralogists, is extremely doubtful. What has been regarded as a native oxyd of the metal, appears to be rather an earthy carbonate.

Affay and Analysis of Lead Ores.—The most common lead ore, galena, is very easily analysed, since it is in general composed of sulphur and lead only. Those ores in which the lead is combined with other metals, such as silver, copper, antimony, bismuth, or arsenic, are attended with more difficulty in their analysis. If the analysis be made with a view to smelt the ore, it will be proper to make the affay in the dry, as well as the humid way. The latter will not only give the proportion of lead, but its other constituents, by which the smelter is directed to use the most proper fluxes. When, however, the analysis is made for publication, it should be made by the humid process only, and with the greatest accuracy.

The common galena may be analysed by dissolving 100 grains in dilute nitric acid: the lead will be dissolved, and the residuum will be sulphur, which may be separated by washing. The solution of lead may now be treated with sulphat of soda. The lead will be precipitated, with the sulphuric acid in the state of sulphat of lead. The precipitate being collected, and dried at the temperature of 212, must be weighed, allowing for every 100 grains of the sulphat 69.85 of lead. The lead may be precipitated from the nitric acid, in the metallic, by means of a plate of zinc. The metallic lead will adhere to the plate, and may be scraped off and squeezed into lumps, after being washed in clean water. The lead obtained by this process is supposed to contain a small portion of the zinc. It will, therefore, be proper to digest the metallic precipitate, for a short time, in very dilute sulphuric acid, and then wash the lead with warm distilled water.

A specimen of galena containing filix was analysed by Vauquelin.

By slowly roasting a portion of this ore, he found it lost 12 per cent. of sulphur. Another portion was treated with dilute nitric acid, which dissolved the lead. The residuum was heated to redness, by which the sulphur was volatilized, leaving behind 16.76 of sulphur. To the solution in nitric acid was now added sulphat of soda, when the lead was precipitated in the state of sulphat. He obtained 63.1 per cent. of lead, allowing 100 of sulphat to contain 75.72 of metallic lead. He then saturated the liquor with ammoniac, which threw down 3.3 per cent. of oxyd of iron, and obtained from the remaining liquor, by carbonat of potash, 3 per cent. of carbonat of lime.

A specimen of lead ore from Cornwall, consisting of lead, sulphur, antimony, and copper, was analysed by Mr. Hatchet.

To 200 grains of the ore, in a matrafs, he added 2 oz. of muriatic acid. While the mixture was heated, he added, from time to time, small quantities of nitric acid, just to keep up an effervescence, till the metals were oxydated and dissolved. After being gently heated for an hour, the solution was complete, and of a green colour, owing to the presence of the copper. The sulphur was separated and floated on the liquid, which being collected was digested in muriatic acid. When dried it weighed 34 grains.

The above solution, and the muriatic acid in which the sulphur was digested, were mixed together, and diluted with six pints of distilled water. The mixture became turbid and milky, and on being filtered while hot, the pure oxyd of antimony was left on the filter, which being washed with more boiling water, was dried, and found to weigh 63 grains.

When the liquid, which had passed through the filter, including the washings, was cold, some muriat of lead was deposited in crystals, owing to the sparing solubility of that

salt. The whole was evaporated to a small quantity of liquid, sufficient to hold the copper in solution. This liquid, being separated from the solid muriat of lead, contained a small portion of that salt. A few drops of sulphuric acid being added, however, separated it in the state of sulphat of lead. The mass of muriat of lead left by evaporation, was now re-dissolved in boiling water, and decomposed by sulphat of soda. The sulphat of lead here formed was added to that produced from the separated liquid, which, on being washed and dried on a sand bath, weighed 120.2 grains. The green liquid containing the remainder of the mineral was now saturated with ammonia and an excess added, which redissolved the oxyd of copper, forming a vivid blue solution. A quantity of oxyd of iron now subsided, which, when separated, weighed 24 grains.

The solution of copper was now evaporated nearly to dryness, and boiled with pure potash, when the black oxyd of copper was left at the bottom of the vessel, which being washed, separated, and dried, weighed 32 grains.

In this analysis the sulphur is the only substance separated in a state of purity. The 63 grains of oxyd of antimony, allowing it to contain 23.08 per cent. of oxygen, would afford 48.46 of antimony. The 120.2 grains of sulphat of lead, allowing 70.9 to the 100, will give 85.22 of metallic lead. The 32 grains of oxyd of copper, reckoning the black oxyd of that metal to contain 25 in the 100, will yield 24 grains. If we reckon the 2.4 grains of iron at 1.2 of metal, the analysis will stand as follows, when reduced to 100.

Sulphur	-	-	-	17
Antimony	-	-	-	24.46
Lead	-	-	-	42.61
Copper	-	-	-	12
Iron	-	-	-	1.2
				<hr/>
				97 27
Loss	-	-	-	2.73
				<hr/>
				100
				<hr/>

If silver had been a constituent of the ore, the above process would have been a little varied. In the first operation the ore would have been dissolved in dilute nitric acid, the antimony would have been in part dissolved, and left at the bottom of the vessel in the state of white oxyd. When the sulphur and the antimony, by dilution with water, are separated, muriatic acid must be added. The lead will be in part, and the silver entirely precipitated. The muriat of lead may be separated, by boiling water, from the muriat of silver. The weight of silver may be rated at 77.52 in the 100 of muriat. The other metals may be separated as in the last process. Arseniated lead ore requires a still different treatment. It was analysed by Vauquelin as follows: 100 parts of ore were roasted for half an hour, occasionally adding a little tallow, which served to reduce the arsenic and facilitate its escape. By this treatment it lost 38 parts, which was presumed to be oxyd of arsenic; the remaining mass was boiled with strong muriatic acid for an hour. A quantity of oxymuriatic acid escaped, the liquid assumed a red colour, and white needle-formed crystals of muriat of lead were deposited. The lead by this means was converted into a muriat, which being dissolved in boiling water, and treated with sulphat of soda, affords sulphat of lead. This precipitate, being separated and dried, weighed 25 parts, which gave 20.2 of lead, allowing 80.8 to the 100 of sulphat. The liquid thus freed from lead being treated with pure ammonia, afforded a precipitate equal to 39 grains, consisting of oxyds of iron and arsenic. The circumstance of oxymuriatic acid being given out, when the oxyd of lead was di-

gested with muriatic, induced Vauquelin to conclude that it was in a state of peroxyd.

In this account the last part of the process appears incomplete, in the circumstance of the oxyds of arsenic and iron being mixed together. The former of these may be separated, boiling the two in nitromuriatic acid, which will convert the oxyd of arsenic into arsenic acid, and which may be separated by washing.

Carbonat of lead was analysed by Klaproth by the following process. He introduced 100 grains of this ore into 200 grains of nitric acid, and diluted it with 300 of water. The carbonic acid escaped in the form of gas, making a loss of weight equal to 16 grains. Into this solution was suspended a cylinder of zinc. In 24 hours the lead was precipitated in the metallic state, which weighed 77 grains, equal to 82 of oxyd.

Sulphat of lead has been analysed by the same chemist: 100 grains of the ore were first roasted at a red heat, and lost two grains, supposed to be water. The remainder was then heated to redness in a platina crucible, with 400 grains of carbonat of potash. By this treatment a yellow reddish mass was obtained, which, on being digested in water and filtered, afforded 72 grains of oxyd of lead. This was next dissolved in nitric acid, leaving a residuum of one grain of oxyd of iron. A cylinder of zinc was introduced into the solution, which precipitated the lead in the metallic form, in quantity equal to $66\frac{1}{2}$ grains.

The alkaline matter which passed through the filter contained the sulphuric acid of the sulphat of lead, with excess of alkali; this excess was saturated with nitric acid, and the liquid acetat of barytes was added, which caused a precipitation of 73 grains of sulphat of barytes: this he allows to contain 25 grains of real sulphuric acid. Hence the result is

Oxyd of lead	72
Sulphuric acid	25
Oxyd of iron	1
Loss by roasting	2
	<hr/>
	100

We have also the analysis of phosphat of lead by the same ingenious experimenter.

One hundred grains of this native salt were dissolved in dilute nitric acid; into this solution nitrat of silver was dropped till it ceased to precipitate: the insoluble substance, which was muriat of silver, weighed 11 grains, indicating 17 grains of muriatic acid. Sulphuric acid was now added to precipitate the lead. The sulphat of lead weighed 106 grains, which contained 78.4 of oxyd of lead. The excess of sulphuric acid was separated by adding nitrat of barytes, and then nearly neutralized with ammonia. On adding acetat of lead, 82 grains of phosphat of lead were precipitated, containing 18.37 of phosphoric acid: muriatic acid was now added to the solution, and evaporated to dryness. The dry mass was digested with alcohol, which dissolved the muriat of iron, the presence of which was detected by prussiat of potash, and was found equal to $\frac{1}{10}$ th of a grain of the oxyd.

Molybdat of lead was analysed by Mr. Hatchett. He boiled a quantity of the ore in sulphuric acid, till it would dissolve no more. This formed sulphat of lead, while the molybdic acid was dissolved in the sulphuric acid. The sulphat of lead was boiled with carbonat of soda, and was afterwards washed: this appeared to be carbonat of lead. The nitric acid dissolved all but a small quantity, which was found to be filix. The lead was next precipitated by sulphuric acid. The solution of the molybdic acid in the sul-

phuric acid was diluted with 16 parts of water, and saturated with ammonia; when a little oxyd of iron was precipitated. The solution was now evaporated to dryness, and a strong heat given to sublime the sulphat of ammonia. The remaining mass, when boiled with nitric acid to dryness, afforded molybdic acid of a yellow colour.

Although the analysis of the different ores may have pointed out general methods for the separation of lead from other metals, some hints may, nevertheless, be necessary for the analysis of the alloys of lead. Lead is most frequently alloyed with tin, silver, antimony, or bismuth. The alloy of tin and lead may be dissolved in dilute nitric acid. The lead will be entirely taken up. Most of the tin will be precipitated in the state of white oxyd, by the addition of water. If sulphuric acid be now dropped into the solution till the precipitation ceases, the lead, in a state of sulphat, will be obtained, while the remaining tin will be dissolved, which may afterwards be precipitated by an alkali. Lead may be separated from silver, when both those bodies are dissolved in pure nitric acid. The silver may be precipitated in the state of muriat, by adding muriat of soda. The lead may be afterwards precipitated by sulphuric acid.

To separate lead from bismuth, dissolve the alloy in nitric acid, then add a large quantity of water, which will precipitate the greatest part of the bismuth in the state of white oxyd. The lead must then be precipitated by sulphat of soda, and the remainder of the bismuth by potash.

The separation of lead from antimony may be performed by the same process used for separating tin.

It may be here noticed, that in all cases where sulphur is present in the ore or substance to be analysed, if the nitric acid be employed, it must be very dilute, otherwise the sulphur will combine with its oxygen, forming sulphuric acid. In order to know when this takes place, the solution must be tested with nitrat of barytes. If, however, lead be present, it will combine with the sulphuric acid as it is formed, and fall to the bottom of the vessel.

Reduction of the Ores, or smelting of Lead.—Two processes are employed for the smelting of lead, the one by means of a blast furnace, called an ore-hearth, and the other by means of a reverberatory furnace. The latter is used throughout Derbyshire and North Wales, and is undoubtedly the best, where coal is not very scarce. In the former of these methods the ore and the fuel are mixed together, and exposed to the blast. The heat dissipates the sulphuret, the ore being the common sulphuret of lead or galena. A portion of the lead is oxydated, which facilitates the vitrification of the earthy parts of the ore, and of the fuel. These together constitute the slag or scoria. The metallic lead falls into the lower part of the hearth, and is defended from the oxygen of the blast by the scoria, which is fluid upon its surface. The liquid lead is let off from time to time, always retaining a portion for the scoria to float upon. When the whole of the lead is to be drawn off, the blast must be stopped, and some lime thrown upon the liquid scoria, which renders it concrete, while the lead, being still liquid, can be run off.

The reverberatory furnace employed for smelting lead is made on the same plan with those commonly used for puddling iron, differing in size, and a few other particulars. The fire is made at one end, and the flame plays over the hearth, entering an oblique chimney at the end, which terminates in a perpendicular one, of considerable height. The length of the hearth, from the place where the fire enters, to the chimney, is 11 feet; two feet of this length next the fire constitutes the throat of the furnace; the width of the same is four feet, and its depth about six inches; the

length of the fire-place is four feet, equal to the width of the throat; its width two feet, and depth three feet, from the grate up to the throat of the furnace. The rest of the hearth is a concave surface, nine feet long, four and a half feet wide at the throat of the furnace, seven feet four inches wide at the distance of two feet from the throat, seven feet two inches in the middle of the hearth, five feet eleven inches at two feet distance from the chimney, and two feet ten where the flame enters the chimney at two apertures, each ten inches square. These apertures terminate in the oblique part of the chimney, the section of which is 16 inches square, which communicates with the main chimney, the section of which is twenty inches square, supposing a straight horizontal line, drawn from the lower plane of the throat of the chimney to the opposite side of the furnace; the lowest part of the concave hearth, which is in the middle of this cavity, is nineteen inches below this line, the roof of the furnace being seventeen inches above the same line: the rest of the hearth is conformably concave.

On each side of the furnace are three openings, each about ten inches square, provided with iron doors, to be removed as occasion may require. They are arranged at equal distances from each other, between the commencement of the hollow hearth and the entrance into the chimney. The lower part of these apertures is on a level with the horizontal line above alluded to, being for the purpose of stirring and raking the ore, &c. Besides the larger openings there are two small apertures, one below the large middle opening, and nearly on a level with the bottom of the furnace; the other under that next to the chimney, at some distance above the first aperture. The first is a tap-hole for the lead, and the second for the scoria. The ore is introduced by a vessel in the shape of a hopper, placed in the roof of the furnace.

Previous to the ore being smelted, it requires to be separated as much as possible from the earthy matter in which it is imbedded. Although galena, which is the ore used for smelting, is most frequently accompanied by sulphat of barytes, fluats and carbonat of lime, it is found to exist in crystallized distinct masses, and can be separated from it by mechanical means to a tolerable extent. The whole of the ore, with the earthy matter, is pounded to a certain degree with hammers, and is chiefly performed by women. In some places, however, it is broken down by passing it through iron rollers pressed together by great weights. After the ore has been thus reduced, the earthy matter is separated by washing. The powder to be washed is introduced into a sieve or riddle, and placed in a large tub full of water. By a certain motion given to the riddle, the lighter or earthy parts are thrown over the edge of the same, while the galena, by its greater specific gravity, is retained. This process requires great dexterity, which can be acquired by experience only. There are, however, some impurities which cannot be separated by this mechanical process, and are generally smelted with the ore. These are *blind*, or *black-jack*, called by the smelter *mock ore*; pyrites, or sulphuret of iron, named *Brazil* by the workmen. When the ore abounds much with these substances, the process of smelting is more difficult, and requires an extra assistance of flux to reduce it.

In the state above described, the ore is introduced at the hopper in the middle of the roof of the furnace, and spread upon the concave hearth, to expose it as much to the flame as possible, in order to facilitate the escape of the sulphur. This should be performed by a long continued heat which is not violent, in order that the sulphuret itself may not be volatilized, an effect which, more or less, always takes place. The moment the sulphur has left the lead it begins

to combine with oxygen. The oxyd of lead, thus formed, combines with the earthy matter, which it renders so fusible as to become liquid upon the sulphur of the melted lead, and defends it from the future action of the oxygen. At this stage of the process the fire is raised to separate as quickly as possible the melted lead from the liquid scoria. The latter is now let off at the upper tap hole, leaving a small portion still upon the lead to preserve it from the air. The fire at this period is lowered, and a quantity of coal-slack thrown in upon the melted mass. This serves as well to facilitate the cooling, and to cause the reduction of some oxyd of lead, which also tends to stiffen the melted scoria. This last effect, however, is not produced sufficiently, till a quantity of powdered lime is thrown into the furnace. By this treatment the remaining scoria becomes concrete, and is then broken to pieces and pushed to the opposite side by means of a rake, and taken out of the furnace at the different openings on the same side. The liquid lead is now let out, at its proper aperture, into a large iron pan, or cistern, from whence it is laded into moulds to cast into pigs. The furnace is now ready to be charged again. When the ore abounds with much impurity, the oxyd of lead is not sufficient to give the proper degree of liquidity to the scoria. In this case a certain quantity of fluat of lime is added, which has the property of forming a very fusible compound with sulphat of barytes, an ingredient very common in the ore.

This flux has been used from time immemorial for the same purpose, and has no doubt derived its name from its properties as a flux. See *Fluat of LIME*.

The concrete scoria, which is taken out of the furnace, is found to contain some lead, independent of that in the state of oxyd, and chemically combined. This is generally lodged in the cavities of the spongy mass. These masses are taken to a kind of blast furnace, called a *slag-hearth*. By this second fusion of the scoria, the lead drops through the liquid mass into the lower part of the hearth, where it is not acted upon by the blast, and from thence is let off and cast into pigs. This lead is said to be of an inferior quality. Some ores of lead contain silver. The great affinity of lead for that metal is such, that the whole of it is found in the lead (see *SILVER*), from whence it is afterwards separated.

Physical and chemical Properties of Lead.—Lead is of a bluish-white colour, when made as bright as possible. This is best effected by scraping and burnishing. This polish it soon loses by exposure to air.

Its softness is such, that a cylinder of one inch in diameter and twelve inches long, may be easily bent by a person of ordinary strength: indeed, it is the most soft and flexible of the metals. Its specific gravity, according to Brisson, is 11.3523, and so far from being increased by the hammer, agreeably to that change in other metals by the same effect, Muschenbroeck asserts that it is diminished. It may be here proper to observe, that those metals which are susceptible of the most perfect crystallization, will undergo the greatest condensation by the hammer, provided the metal be sufficiently malleable. Hence we find this property the most conspicuous in brails, and in blistered steel. See *METAL*.

Lead, in common with its softness, is the least elastic of the metals; to which also may be attributed its little tenacity. Its hardness is increased by hammering, and its tenacity in a proportionate degree.

Lead is exceedingly malleable, which connected with its excessive softness, admits of its being rolled into thin sheets with little power. Its tenacity, according to Dr.

Thomson, is such, that a wire of $\frac{1}{12.6}$ of an inch will support only 18.4 pounds. Lead fuses at about 600° of Fahrenheit, and if raised to a much higher temperature, will be found to diminish by evaporation. If lead be melted and poured into an iron mould, it will be found to concrete on the sides next the mould, while the middle part will be liquid for a short time. If this liquid part be poured off, or let out at a plug-hole at the bottom, the interior surface of the solid part will exhibit a crystalline form. The crystals will be larger and more distinct as the cooling is slower.

Lead is much employed in the arts, particularly for buildings and cisterns. For the former of these purposes it has many advantages. It is easily worked into any shape on account of its great softness, and is sufficiently malleable to fold two edges over each other, so as make it watertight without soldering. This is a very great advantage, since, when the pieces are soldered together, the expansion and contraction, by a change of temperature, soon breaks it to pieces.

Although it is at present in general use for water-cisterns, pumps, and pipes for conveying water, serious objections have been made to it by different philosophers, particularly Dr. Lambe, so far as regards its effects on the human economy.

A very ingenious paper was some time ago published by Morveau, in which he shews that the water exposed to the leaden vessels would frequently be pernicious, if some sulphuric acid were not present, which never fails to precipitate lead from any of its solutions. Thus we see that lead is the least objectionable for mineral waters containing the sulphuric acid, which is very general in almost all springs.

Great mischief has been produced by the use of lead in dairies; although we lament to say that this practice is still followed up to a certain extent. If the milk runs into the slightest acidity, we must expect some lead to be dissolved, and its probable consequences if taken into the stomach.

The disease called the Devonshire colic, was proved by Sir George Baker, in several excellent papers written by him, and published in the Philosophical Transactions of that time, to be occasioned by lead dissolved in the cyder, and which had been furnished from the cyder presser, which were lined with that metal; but was in consequence of this valuable discovery laid aside.

We have heard of a similar disease in the West Indies, acquired by drinking new rum. The rum was found to contain lead, which had been taken from the leaden worm used for the condensation of the spirituous vapour. What, however, is very singular, the rum lost its deleterious property by keeping about twelve months. This fact was not explained at the time, but it has lately been cleared up by a series of experiments made by the writer of this article. The new rum is generally put into oak casks, from whence the liquor extracts a quantity of tan and gallic acid. These substances combine with the lead in solution, forming a perfectly insoluble substance, which falls to the bottom of the cask. These facts shew that lead should not be used in any situation where fermented liquors are present, since in every stage of their existence, they contain more or less acetic acid. And it must not be forgotten, that all distilled spirits will contain the same acid, from the circumstance of its being volatile and coming over with the spirit.

We have, however, abundant satisfaction in knowing that the existence of lead and gallic acid in spirits, wines, or

other fermented liquors, are incompatible: and that all liquors which have been kept in oak casks for a certain time must be freed from lead. If we find the presence of gallic acid by a solution of iron, we may pronounce such liquid free from lead.

These observations, which may appear out of place, are given with a view to guide those who may be making or using vessels of lead, which, under some circumstances, are attended with deplorable consequences.

Alloys of Lead formed with other Metals.—One part of tin and two of lead form an alloy, fusible at about 350° of Fahrenheit, and used by tinmen and others under the name of soft solder. See SOLDER.

Lead forms an imperfect alloy with copper. The metal used for common brass-cocks is an alloy of these two metals. The lead is so imperfectly combined with the copper, that when a piece of the metal is exposed to a certain heat, the lead separates from the copper in bright globules of the former.

The alloy of antimony with lead is not uncommon. Sixteen of lead and one of antimony form the printers' type metal.

Lead easily combines with mercury, forming an amalgam. This is effected either by putting mercury into melted lead, or by putting lead, in small particles, to the mercury. See AMALGAM.

An alloy of silver and lead is easily formed. Indeed lead is frequently used to take silver from plated iron, which is afterwards got from the lead by cupellation.

We are indebted to Mr. Hatchett for some valuable facts relative to the alloys of lead and gold. One part of lead to eleven of gold forms a very brittle alloy, having a fracture of a pale brown colour, destitute of metallic lustre.

The alloys in any proportion have the singular property of being of less specific gravity than the mean, the very contrary of which is observed in most other compounds of metals. The following is a table given by Mr. Hatchett exhibiting these facts.

Metals.	Grains.	Specific Gravity of Alloy.	Bulk before Union.	Bulk after Union.	Expansion.
Gold Lead	442 38	18.08	1000	1005	5
Gold Copper Lead	442 19 19	17.765	1000	1006	6
Gold Copper Lead	442 30 8	17.312	1000	1022	22
Gold Copper Lead	442 34 4	17.032	1000	1035	35
Gold Copper Lead	442 37.5 .5	16.627	1000	1057	57
Gold Copper Lead	442 37.75 .25	17.039	1000	1031	31

When lead is exposed to the air for a little time, it soon appears of different colours, not unlike the prismatic colours. By a longer exposure, assisted with moisture, it becomes covered with a white powder. This is the oxyd of lead combined with carbonic acid. This change is facilitated by heat, and still more by the fumes of acetic acid or vinegar. It is by this means that the white lead of commerce is made, of which we shall treat hereafter.

If melted lead be exposed to the oxygen of the atmosphere, a greyish-yellow powder begins to form upon the surface. By keeping it exposed for some time, the powder becomes more yellow. In this state it is called *massicot*, or yellow oxyd of lead. It contains about 6.88 of oxygen.

This oxyd is made, in the large way, in a furnace not unlike a baker's oven. The middle of the hearth contains a recess for exposing the melted lead. On each side, and a little below the level of the hearth, is a fire, the flame of which passes slowly over the hearth, giving sufficient heat to keep the lead melted, and passes up a chimney near the mouth of the furnace. As soon as the lead is melted, a person is constantly employed to agitate it, in order to expose greater surface to the air. This manual operation is performed by a rake suspended from a chain, so that the perpendicular part of the rake dashes through a portion of the melted lead, by merely moving it backwards and forwards. By the same motion, the oxyd which is formed is pushed away from the surface of the lead, leaving it free to the action of fresh oxygen. This process being kept up, the lead is at length converted into a greenish-yellow powder, mixed with lumps of metallic lead. This powder is ground in a mill and then washed, by which means the metallic lead is separated, and the powder becomes of a more bright yellow. The green colour was therefore owing to a mixture of the blue particles of lead, mixed with the yellow oxyd. The yellow oxyd here produced is called *massicot*; which see.

This oxyd appears capable of combining with more oxygen by a second exposure. For this purpose the yellow powder, after being washed and dried, is returned into the furnace above-mentioned, or one of similar construction, kept for this second process only. The heat is kept uniform but not great, and the oxyd raked about to expose as much surface as possible. It gradually changes colour, and ultimately assumes a splendid red. In this state it is called *minium*; which see. Although during this process the oxyd appears gradually to pass through all the shades of orange colour from yellow to red, the two latter can only be considered as distinct oxyds, the intermediate tints being mixtures of the two.

If we consider the yellow as the first or protoxyd, the red will be the second, and the brown, yet to be treated of, the third and the peroxyd. Proust, however, has given some reason to believe that the yellow is not the first. The oxyd which is precipitated from the nitric acid when heated to redness, to drive off the water and carbonic acid, is found to be the yellow oxyd in a very perfect state. The author above-mentioned informs us, that if crystals of the common nitrat of lead be heated with some pieces of metallic lead, scaly yellow crystals are formed. This salt, decomposed by potash, affords an oxyd which Proust supposes to contain less oxygen than the yellow. Dr. Thomson repeated his experiment; he found the oxyd not to differ in appearance from the yellow, and makes it to consist of lead, 91.5 lead, and 8.5 oxygen. This appears to be rather less oxygen than, according to his own analysis, is contained in the yellow. But there is reason to believe, that in Dr. Thomson's analysis of the yellow oxyd, the oxygen is rated too high. The

same oxyd, according to Bucholz, is composed of 100 lead and eight of oxygen, equal to 7.4 per cent. This analysis appears to have been made under such circumstances as to entitle it to much credit. From the average of three analyses of the yellow oxyd, obtained from acetat of lead, the writer of this article made the oxygen 7.4 per cent. Hence we have abundant reason to doubt the existence of an oxyd below the yellow oxyd, since it appears, from Dr. Thomson's own account, that the oxyd, said to consist of less oxygen than the yellow, contains 8.5 per cent., being 1.1 more than Bucholz makes the yellow oxyd.

If nitric acid in sufficient quantity be added to the red oxyd of lead, nearly the whole will be dissolved; $\frac{1}{3}$ th of the oxyd will remain at the bottom of the vessel, which, when collected and dried, is of a dark brown colour, and is called the brown oxyd of lead. The following process is given by Vauquelin: Mix a quantity of the red oxyd of lead with water in a Woulff's apparatus, and let the oxymuriatic acid gas pass through the mixture. The oxyd gradually becomes of a deeper colour, and is at last dissolved. From this solution the brown oxyd is precipitated by potash. From every 100 parts of the red oxyd 68 of the brown may be obtained.

This oxyd is of a flea-brown colour, having no smell or taste. It is insoluble in any of the acids. It converts the muriatic into oxymuriatic acid, by giving up a portion of its oxygen. When rubbed briskly in a mortar with powdered sulphur, the sulphur inflames, producing a strong smell of sulphurous acid. According to the analysis of Proust, this oxyd is composed of 79 lead and 21 oxygen. Dr. Thomson makes it 81.6 lead and 18.4 oxygen.

It appears highly probable that we have only three oxyds of lead, namely, the yellow, the red, and the brown. The first, according to Proust, contains 9 per cent.; Thomson, 10.3; Bucholz, 7.4; the writer of this article, 7.4: the average of all these being 8.5. The red oxyd, by Dr. Thomson's analysis, contains 12 per cent.: the brown, according to Proust, contains in the 100, 21 oxygen; Dr. Thomson makes 18.4: the mean of these is 19.7.

Agreeable to the average results of these different analyses, we cannot help being forcibly struck with the beauty of Mr. Dalton's hypothesis relative to the limited proportions with which bodies combine. He makes the atom of lead to weigh 95, or to be 95 times heavier than an atom of hydrogen; the atom of oxygen being 7 times heavier. In referring to the doctrine advanced by this ingenious chemist, it will be seen that he holds the necessity of bodies combining atom to atom, or in some multiple of the same; as, 2 to 1, 3 to 1, &c. The first oxyd of lead, agreeably to the above data, must be 1 to 1, or 95 to 7; the second oxyd, 95 to 14; and the third, 95 to 21. Hence these proportions reduced to 100, will stand as follows: $\frac{95 + 7}{7}$

$$= \frac{100}{6.86}, \text{ or } 6.86 \text{ in the } 100, \text{ for the first oxyd. Then,}$$

$$\text{for the second, } \frac{95 + 14}{14} = \frac{100}{12.84}, \text{ or } 12.84 \text{ in the } 100.$$

$$\text{Lastly, for the third or peroxyd, } \frac{95 + 21}{21} = \frac{100}{18.1}, \text{ or}$$

18.1 in the 100. The proportions by analysis give, for the first, 8.5; second, 12; and the third, 19.7: by theory, 6.86, 12.84, and 18.1.

The second and third oxyds of lead give out oxygen, by exposure to heat in a crucible, and are reduced to the state of the first oxyd. If the heat be raised a little above red-

ness, the yellow oxyd fuses into a glass, in which state it is called the vitreous oxyd of lead. It becomes so exceedingly fluid, as to run through the common crucibles. In this state it has the power of oxydating, and combining with the oxyds of all the metals which are oxydatic, by exposure to air with heat: and hence is employed to great advantage in the cupellation of the nobler metals. See SILVER.

When lead is oxydated at a high temperature, such as that employed in the separation of silver from lead, the yellow oxyd fuses as it is formed, and is blown from the surface of the lead by bellows. In this state it is called *litharge*; which see. It consists of the yellow oxyd, united to a portion of carbonic acid. For this part we are indebted to Dr. Thomson.

Lead combines with sulphur and phosphorus.

Sulphuret of lead may be formed by projecting sulphur into melted lead, or by stratifying thin plates of the metal with the sulphur. The compound is very brittle, of a dark grey colour. It may be crystallized by slow cooling; under which form it exhibits a brilliant fracture, resembling the native sulphuret, or *galena*. This sulphuret, according to Dr. Thomson, consists of 86 lead and 14 sulphur. According to Dalton's hypothesis, it consists of one atom of lead to one of sulphur: the former atom being 95, and the

latter 13, will give $\frac{95 + 13}{13} = \frac{100}{12}$, or 12 to 100; which

agrees with several other analyses very nearly.

Lead appears capable of combining with a second dose of sulphur, constituting a compound, which is more brilliant, and of a lighter colour. It may be easily distinguished from the common kind, by its burning in the flame of a candle.

It is called the *super-sulphuret of lead*, and, according to Dalton's hypothesis, must consist of one atom of lead and

two atoms of sulphur, which would give $\frac{95 + 2 \times 13}{26} =$

$\frac{100}{21.5}$, or 21.5 per cent. Dr. Thomson makes it 25 per cent.

It is to this chemist we are indebted for our knowledge of this substance.

Phosphuret of lead may be formed by mixing together equal parts of filings of lead and phosphoric glass; the mixture being fused in a crucible. It is of a silvery blueish-white colour. It possesses slight malleability, and may be cut with a knife. It is composed of 88 lead and 12 of phosphorus. Dalton makes the atom of phosphorus to weigh 9:

hence this compound of 1 to 1 will give $\frac{95 + 9}{9} = \frac{100}{8.6}$.

Salts of Lead—Most of the acids combine with the yellow oxyd of lead, forming peculiar compounds. By far the greatest proportion of these compounds is insoluble in water. All those which are soluble have a sweetish taste, attended with a roughness which it leaves on the tongue, similar to that of red port, and some other wines. This property has caused it to be used for the villainous purpose of mixing with sour wine, which does not only take up the acid, but adds a roughness and sweet vinous flavour, exceeding imposing upon the palate. Some have suspended bags of shot in the casks of wine; others have added common white lead.

Mankind are now so well acquainted with the different tests for lead, that it is very seldom found in those liquors. Water impregnated with sulphuretted hydrogen gas will

instantly turn wine muddy and black, which contains lead. If a solution of iron be dropped into wine, and it turns black, the presence of gallic is indicated: and from what we before observed, the existence of lead and that acid are incompatible in the same liquid.

Sulphat of Lead.—Lead is scarcely acted upon by the sulphuric acid, in the cold. If the acid be boiled with the lead, fumes of sulphurous acid will be given out, and a portion of the lead oxydated, which combines with the acid, forming a whitish pasty compound. If the acid be in excess, and the mass washed in water, the substance becomes divided into two portions, namely, the sulphat of lead, which is insoluble, and the superfulphat, which is slightly soluble, and will be deposited in crystals.

It is from the circumstance of the insolubility of the sulphat of lead, that the metal can be used with such advantage for the lead houses, used in making sulphuric acid, and for making vessels which have to hold this acid. The sulphat which first forms upon the surface defends the lead not only from the action of this acid, but from any other solvent of this pernicious metal. Sulphat of lead may be best formed by adding sulphat of soda to the acetat of nitrat of lead. A dense white precipitate is formed, which is sulphat of lead. This salt is produced in great abundance by the calico-printers, in making acetat alumine, with alum and acetat of lead. It forms an excellent paint with oil, for standing the action of acids.

Kirwan gives the proportion of this salt at 23.37 acid, 75 acid yellow oxyd, 1.63 water in the 100; Bucholz, 24.72 acid, 75.28 oxyd; and Klaproth, 26.5 acid, and 73.5 oxyd: the mean of these is 24.86 acid, and 75.14 base. Calculated by Dalton's theory, the atom of sul-

phuric acid weighs 34: therefore, $\frac{95 + 7 + 34}{34} = \frac{100}{25}$;

or, the acid is 25 in the 100: then, $100 - 25 = 75$ the base.

Sulphite of Lead.—The sulphurous acid has no action upon lead: but it combines with the yellow oxyd, forming an insoluble compound, having no remarkable properties. When exposed to a red heat, the acid is disengaged, in the form of gas.

When the sulphurous acid is added to the red oxyd of lead, the acid takes oxygen from the oxyd, reducing it to the state of yellow oxyd. The acid is converted into the sulphuric, and combines with the oxyd, forming the sulphat of lead.

Dr. Thomson gives the proportions at

74.5 oxyd,
25.5 acid.

100

Nitrat of Lead.—When the nitric acid is a little diluted, it acts with considerable rapidity upon lead. If it be a little assisted by heat, the whole will become speedily dissolved, forming nitrat of lead. This consists of the yellow oxyd of the metal united to a portion of the acid. If the solution be evaporated, it affords crystals of tin, in six-sided pyramids of a silvery white colour. This salt dissolves in $7\frac{1}{2}$ of boiling water. When the crystals are heated, they undergo a slight detonation: the same takes place when they are rubbed with sulphur in a hot mortar.

According to experiments of Dr. Thomson, this salt consists of,

66 oxyd,
34 acid.

When the crystals of the last salt are boiled with metallic lead, yellow scaly crystals are formed, constituting, according to Dr. Thomson, a subnitrat, consisting of

81.5 oxyd,
18.5 acid,

100

By Dalton's theory the weight of an atom of nitric acid is 19: in most of the nitrats he supposes one atom of the base to unite with two atoms of acid. The nitrat of lead, already described, should, according to the above analysis, consist of at least two atoms of acid to one of base, for

$$\frac{102 + 2 \times 19}{38} = \frac{100}{27.14} = 27.14 \text{ of acid, and } 72.86 \text{ of base.}$$

The acid here falls considerably short of that in the analysis of Dr. Thomson. The latter salt, which we have called the subnitrat, should have one atom less of acid.

Hence $\frac{95 + 7 + 19}{19} = \frac{100}{15.7}$, which gives 15.7 acid, and 84.3 of oxyd = 100.

Muriat of Lead.—Muriatic acid has a very feeble action on lead, but it readily dissolves the yellow oxyd, forming the muriat of lead. This salt may be also formed by adding muriat of soda to nitrat of lead. The precipitate which is formed is the salt in question. It dissolves in 22 parts of cold water. This is the fact only when no excess of this acid, or when no other acid is present; since the salt is soluble in most acids to a greater extent than in water. When this salt is mixed with the sulphat of lead, it may be separated from it by its solubility in the acetic acid. Muriat of lead is much more soluble in hot than in cold water. Hence, when a saturated hot solution is suffered to cool, the salt is deposited in crystals of a silvery-white colour. When heated they readily melt, and on cooling assume a slight transparency, from which it has been called *Plumbum corneum*.

On the application of greater heat some of the salt evaporates in a white smoke, leaving behind a substance, which is said to be a submuriat of lead.

The composition of muriat of lead is, according to Klaproth,

Acid 13.5
Oxyd 86.5

10

By Kirwan's account,

Acid 17
Oxyd 83

100

The weight of the atom of muriatic acid being 22, we shall have by Dalton's theory $\frac{95 + 7 + 22}{22} = \frac{100}{17.74}$, by

which we have 17.74 acid, and 82.26 of oxyd, which comes very near to Kirwan. When the muriatic acid is poured on the red oxyd of lead, the lead gives up a part of its oxygen to the muriatic acid, constituting the oxymuriatic acid. The muriatic acid then unites with the yellow oxyd thus formed, while the oxygen is returned to the remaining red oxyd, forming the brown oxyd.

The substance above-mentioned, said to be a submuriat, appears rather ambiguous, and may, perhaps, be a mere mixture of the common muriat with the yellow oxyd of lead. There is, however, one argument in favour of its being a proper compound. It is said not to be soluble in water, or that the excess of oxyd is attached to the muriat, so as to prevent its being separated by the affinity of the water for the salt.

The common way of forming this substance is by adding to the muriat of soda a much larger quantity of litharge than would be necessary to saturate the acid of the salt. We are indebted to Vauquelin for the best account of the nature of this anomalous decomposition. At the same time the muriat of lead is decomposed by soda. We have the fact before our eyes, that an oxyd of lead will completely decompose the muriat of soda. If we state the experiment of Vauquelin we shall be better able to give an opinion. To one part of muriat of soda he added seven of litharge in fine powder, with as much water as made the mixture of the consistency of thin soup. This was frequently stirred for several hours. The litharge gradually lost its colour, and ultimately became white. It increased in bulk, and so much water was absorbed as to make it necessary to add more. At the end of four days the chemical action had entirely subsided, when the result was examined. The liquid part, when separated by the filtre, had a strong taste of soda, with a taste of muriat of lead, but no muriat of soda was present. The liquid afforded crystals of carbonat of soda by evaporation. The substance from which the liquor had been separated, when washed and dried, was of a dirty white colour, and was found to have increased in weight $\frac{1}{4}$ th of the whole oxyd employed. When this substance was heated to a certain degree it assumed a fine yellow colour, by which it lost $\frac{1}{4}$ th of its weight. This was, perhaps, carbonic acid and water.

Some caustic soda was added to a part of this substance, which changed its colour to that of a dirty yellow, and the residuum was found to be a mass of crystals of muriat of lead. By the test of an alkaline hydro-sulphuret, the soda appeared to hold a great quantity of the oxyd of lead in solution.

The one part of muriat of soda, used in this experiment, consisted of .44 of acid, and .56 of soda. The .44 acid would combine with 2.4 of the yellow oxyd to form 3.84 of muriat of lead, leaving $7 - 2.4 = 4.6$ of oxyd of lead. This is supposing the true muriat to be formed; but if a submuriat were formed, it must consist of more than one atom of lead united to one of acid. Suppose it one of acid to two of oxyd, then $.44 + 2 \times 2.4 = .44 + 4.8 = 5.2$ of submuriat, still there would be free oxyd left. But the author tells us that the yellow substance was insoluble in water, or that the water would not take the muriat from the excess of oxyd, although the nitric acid, as well as the soda, was capable of that effect. If there were no free oxyd when two atoms of lead were to one of acid, let us suppose them three to one, we shall then have $.44 + 3 \times 2.4 = .44 + 7.2 = 7.64$ of a second submuriat. If, therefore, we are to rely upon the fact, that the muriat of lead could not be dissolved, leaving the excess of oxyd, we must regard

this yellow substance as a legitimate compound. If the contrary be the case, we must regard it as a mixture of the true muriat mixed with the yellow oxyd of lead. This substance has been manufactured under a patent by Mr. Turner, of Newcastle-upon-Tyne, and is deemed a valuable pigment for painting.

Phosphat of Lead.—The phosphoric acid does not act upon lead in the cold, and but very feebly by heat. The result of this action is the formation of an insoluble compound, which is the phosphat of lead.

This salt may be more easily formed by adding together the solutions of phosphat of soda and the nitrat, or acetat of lead. A dense white powder subsides, which is the salt in question. This salt is insoluble in water, but it dissolves readily in nitric, and also, when assisted by heat, in the muriatic acid. On the latter solution cooling, crystals of muriat of lead are deposited; a proof that a partial decomposition takes place. It is also decomposed by the sulphuric acid, by the assistance of heat.

When this salt is heated it melts, and on cooling assumes a crystalline appearance.

It is from this salt that phosphorus is generally obtained; for when it is exposed to a great heat, in an earthen retort, with charcoal, both the lead and the phosphorus lose their oxygen, the latter being distilled over.

Mr. Dalton makes the atom of phosphoric acid to weigh 23, then $\frac{95 + 7 + 23}{23} = \frac{100}{18.4}$; so that this salt, from

these data, consists of 18.4 of acid, and 88.6 of oxyd, which is very near the proportions of the native salt.

Carbonat of Lead.—Carbonic acid does not act upon lead, but it combines with the yellow oxyd of lead, forming an insoluble white powder, which is manufactured under the name of *white lead*.

This salt may be formed by adding a carbonat of potash to the acetat or nitrat of lead. The precipitate, being washed and dried, is snowy-white powder, appearing to the eye we've calculated to make a much finer white paint than that made in the common way. Although the carbonat formed by precipitation is, no doubt, chemically the same with the manufactured, their difference, in point of density, is very remarkable. The proportions of the constituents of this salt are, according to Bergman, 16 acid, 84 oxyd; to Chenevix, 15 acid, 85 oxyd; Proust, 16.15 acid, 83.85 oxyd; and Klaproth, 16.33 acid, 83.67 oxyd in the 100.

The manufacture of white lead has been known long before any idea was entertained of its composition, or the theory of the process; and it is rather singular that no more improvement has been made in the common process, which has long appeared to chemists as clumsy and unchemical.

The process consists in exposing thin sheets of lead to the fumes of vinegar at a certain temperature. The lead is cast into sheets about two feet long, five or six inches broad, and about $\frac{1}{4}$ th of an inch thick. These are coiled up, rather spirally, into a cylindrical shape, about five or six inches diameter. The vinegar is placed in the bottom of earthen pots, which are different in size at different manufactures; some holding three pints and others five or six. There is a ledge round the pot, in the inside, about an inch deep, for the purpose of supporting the cylindric coil of lead, which stands upon it like a chimney. The pots thus fitted, with the lead and vinegar, are arranged in rows, upon a stratum of horse-litter, or, what is now used as being cheaper, the refuse bark of tanners. The ends of all the

cylinders of lead are covered with a plate of the same metal; to confine the whole as much as possible to the action of the vapour. The pots thus placed are covered over with litter or bark, and a new stratum of pots arranged in a similar way over them. Several tons of lead are sometimes exposed in this manner at one time. The heat arising from the fermentation of the vegetable or animal matter keeps up a certain temperature, by which the vinegar is slowly evaporated. The vapour oxydates the lead, and the oxyd combines with carbonic acid. This latter substance was formerly thought to be furnished by the fermenting substance in which the pots were imbedded: it is now, however, known, that the vinegar is decomposed, and furnishes the carbonic acid. White-lead works are at present carried on, both on the continent and in this country, in which the heat is furnished by artificial means only; and of course the carbonic acid can come from no other source than that of the vinegar.

After the lead has been exposed to the vapour of the vinegar for about six weeks or two months, the pots are withdrawn, and the coils of lead are found corroded to a considerable thickness. The white carbonat thus formed is very brittle and very hard. The sheets are now passed through rollers for the purpose of breaking the white lead from the uncorroded metallic lead. The powder is now taken to a pair of stones, and ground in a manner similar to corn. After this it is levigated to get it of the greatest possible fineness, and it is then gradually dried in stoves for the purpose.

Density and whiteness are the most valuable properties of white lead. These properties do not depend upon the proportions of its elements, but upon the mechanical treatment. The density in all probability will be greater, as it has been longer forming, by the action of the vinegar being slower. Some of the pieces of white lead, as they are separated from the sheet, are much harder than others, even in the same bed. This hardness and density are sometimes so great as to render the pieces sonorous. In this state it is the most valuable. Hence the whitest and densest pieces are selected for making the beautiful substance called *flake white*.

The value of white lead is easily ascertained by the painters, from the quantity of oil required to give it proper consistency. The greater the proportion of lead to the oil, the greater is said to be the body of the paint, and the greater will be its whiteness. The carbonat of lead made by precipitation, when in a dry state, is much whiter than the best white lead, made in the common way. If, however, equal weights of the two be mixed with oil to make them fit for painting, the precipitated specimen will be found to take a much greater quantity of oil than the other, and its whiteness much diminished. The common white lead will have lost so little of its whiteness, that the contrast will be very strikingly in favour of the latter. This fact is exceedingly apparent, on mixing together transparent media of different densities. The whiteness of snow depends upon the mixture of small particles of ice with air; for when the same are mixed with water, the whiteness disappears. All colourless transparent bodies become white on being reduced to powder. This is observed in pounded glass and in salts which lose their water of crystallization. Whiteness may therefore be said to arise from a confused refraction of light, rather than from reflection. See LIGHT.

Fluat of Lead.—Fluoric acid does not oxydate lead; but it is capable of combining with the yellow oxyd, forming this salt, which is an insoluble compound. It may be

formed better by adding the fluat of ammonia to nitrat or acetat of lead, the fluat of lead falling down in a state of powder.

Borat of Lead.—Boracic acid does not act upon lead. This salt, however, may be formed by adding a solution of borat of soda to nitrat of lead. The borat of lead will be precipitated in the form of an insoluble white powder. This salt, from a vitreous state which the acid is capable of assuming, melts into a colourless glass before the blowpipe.

Acetat of Lead.—Acetic acid has little or no action upon lead when the metal is immersed in it; but the fumes of the acid in contact with air is capable of oxydating lead, as we have shewn in the manufacture of white lead. The oxyd thus formed is easily taken up by the acetic acid, forming a soluble compound of a sweetish and astringent taste. If the solution be evaporated, an excess of the acid being present, the salt is obtained in needle formed crystals, and of the lustre of satin. It dissolves in about four times its weight of water at 60°. It is singular that this salt is decomposed by the carbonic acid. It is from this circumstance that we always find it decomposed, in some degree, by dissolving it in water, which generally contains more or less of that substance. This salt is used in medicine, uncrystallized, under the name of *Goulard's extract*.

The acetat of lead is an article of extensive manufacture in England, France, and Holland.

Common distilled vinegar is first saturated with the yellow oxyd of lead, which is sometimes from the carbonat or white lead, and frequently from litharge: the latter, however, is the cheapest process. The solution should have a little excess of acid, else it does not form the real salt. By slow evaporation this solution crystallizes, in which state it is used in abundance in the arts, particularly by the calico printers, for the purpose of getting the acetat of alumine, by double decomposition with alum.

The analysis of this salt, according to Dr. Thomson, is

26	Acid
58	Yellow oxyd
16	Water

100

From the combinations of the acetic acid, the earths, and alkalis, it appears that the weight of its atom is about 36.

We have hence $\frac{102 + 36}{36} = \frac{100}{26}$, which gives 26 of acid and 74 of yellow oxyd = 100.

Subacetat of Lead.—When the last salt is boiled for some time with the yellow oxyd of lead, a peculiar salt is formed, consisting of two atoms of oxyd, and one of acid. It is less soluble in water than the acetat. It was first noticed by Thenard, to whom we are indebted for the following analysis:

17	Acid
78	Oxyd
4	Water.

If it consists of two atoms of base to one of acid, its analysis, according to the data in the acetat, will be $\frac{2 \times 102 + 36}{36}$

100 which gives 15 acid, and 85 oxyd = 100.

Oxalat of Lead.—This salt is formed by dissolving the oxyd of lead in oxalic acid. In all probability there are two salts of this species. That given by Dr. Thomson is formed

with the second oxyd, and an excess of acid, and is the superacetat. According to Bergman's analysis it contains

41.2	Acid
58.8	Red oxyd

100

The weight of the atom of oxalic acid appears to be 39, and an atom of the oxyd in this salt 95 lead + 14 oxygen = 109, therefore supposing it the super salt $\frac{95 + 14 + 39 \times 2}{39 \times 2}$

= $\frac{100}{41.7}$, which gives 41.7 acid, and 58.3 red oxyd = 100.

The proper oxalat of lead may, no doubt, be formed by an alkaline oxalat being added to the nitrat of lead, the salt being precipitated in a state of insoluble powder. From the above data it ought to consist of 27.7 and 72.3 yellow oxyd.

Tartrat of Lead.—The tartaric acid does not act upon lead; but this salt may be formed by adding an alkaline tartrat to the acetat, or nitrat of lead. The tartrat of lead falls down in the form of white powder. Dr. Thomson gives the analysis of this salt at 37.44 acid, and 62.56 yellow oxyd.

Citrat of Lead.—This is an insoluble compound, formed by adding an alkaline citrat to a soluble salt of lead.

Malat of Lead.—Malic acid has no action on lead; but the acid combines with the oxyd, forming a compound insoluble in water, but soluble in acetic acid. Cyder, which contains an abundance of malic acid, would never contain lead, but from the presence of acetic acid. If acetat of lead be dropped into cyder, a copious precipitate falls down, but if free acetic acid be added, the precipitate is dissolved.

Arseniat of Lead.—The arsenic acid is capable of oxydating lead, and then combines with its oxyd, forming arseniat of lead, which is completely an insoluble compound. It may also be formed by adding the arseniat of potash to a soluble salt of lead. From the analysis of Chenevix it consists of 33 acid, 63 yellow oxyd, and 4 of water. According to Thenard, it is composed of 35.7 acid, and 64.3 of oxyd. See the native arseniat of lead under the mineralogical part of this article.

Molybdat of Lead.—The artificial salt of this species has been little examined. See the native salt.

Chromat of Lead.—This salt may be formed by adding an alkaline chromat to a soluble salt of lead. The salt is precipitated in the form of powder of a reddish-yellow colour. It is soluble in potash and soda, from which it may be precipitated without changing its properties. It is soluble in nitric acid, but it is decomposed by the muriatic and sulphuric acids. See native salt.

The other species of the salts of lead are not of importance.

The alkalis and some of the earths dissolve the oxyd of lead.

Potash and soda, when pure, dissolve the greatest proportion. By exposure to the air, however, the carbonic acid of the atmosphere combines with the oxyd of lead, as well as the potash. The lead is precipitated in a state of carbonat.

These alkaline solutions of lead have the property of staining hair, wool, and horn. The tint commences with a light fawn colour, and ultimately becomes of a deep and beautiful reddish-brown. These colours are not permanent, being quickly faded by exposure to the light and the air.

Lime water, and probably solutions of barytes and strontian, dissolve the oxyd of lead, but in smaller quantity. A liquid formed by boiling lime and litharge in water, has also the property of staining wool, but the colour is somewhat different to that given by the alkaline solution. The brown colour has less of the red and more of the yellow tint. A composition of common pearl-ash, red lead, and quick lime, is used to give horn the appearance of tortoise shell. In effect, this composition is a solution of the oxyd of lead in potash.

Lead, as we have already seen in the preceding part of this article, is much used in building, particularly for covering, gutters, pipes, and in glass windows. For which uses, it is either cast into sheets in a mould, or milled; which last, some have pretended, is the least serviceable, not only on account of its thinness, but also because it is so exceedingly stretched in milling, and rendered so porous and spongy, that when it comes to lie in the hot sun, it is apt to shrink and crack, and consequently will not keep out the water. Others have preferred the milled lead, or flatted metal, to the cast, because it is more equal, smooth, and solid.

The lead used by glaziers is first cast into slender rods, twelve or fourteen inches long, called *canes*; and these, being afterwards drawn through their vice, come to have a groove on either side for the panes of glass; and this they call *turned lead*.

The method of palling or foldering lead for fitting on of imbossed figures, &c. is by placing the part whereon the figure is to be paled horizontal, and strewing on it some pulverized resin; under this they place a chafing-dish of coals till such time as the resin becomes reddish, and rises in pimples; they apply the figure, and rub some soft folder into the jointing; when this is done, the figure will be paled on, and as firm as if it had been cast on.

Lead is much used in varnishes and painting with oil, both as a colour and as a dryer. It is also used in the preparations of enamels and of porcelain as a flux, and makes the basis of the glazing of almost all pottery wares; and by means of lead the most perfect metals are refined and assayed.

LEAD, in Medicine. This metal is celebrated by some chemical writers for its great medical virtues; but after all it seems to be a metal which ought to be given internally with the greatest caution, and to be rather calculated for outward application. Its ore is so poisonous, that the steam arising from the furnaces where it is worked, infects the grass of all the neighbouring places, and kills the animals which feed on it. The poisonous quality of this ore is such, that the people who live in the countries where it is dug, and near the places where it is washed, can keep neither dog nor cat, nor any kind of fowl, but all die in a short time, and it has been known that a little house, in which lead ore had been kept for some time, though afterwards made very clean, and bedded with fern, infected calves which were put into it, so that all died in a very short time; and it is a too melancholy observation, that children often die strangely and suddenly about these places. Philosophical Collections, N^o 2. p. 6.

Its best preparation is *saccharum saturni*, or the super-acetate of lead; which, though capable of doing great good in hæmorrhages, and some other cases, is apt, however, to bring on colics of so violent a kind, that the remedy often proves worse than the disease.

The internal use of lead is dangerous, on account of the colics and palsies that are occasioned by it. Culinary vessels, lined with a mixture of tin and lead, which is the usual

tinning, are apt to communicate to acid foods pernicious qualities, and require to be used with great precaution. The same thing has been also said of liquors kept in glazed ware, and of cyder made in vessels, where lead is used, and of wines adulterated with litharge, &c. See the article **LEAD**, *supra*, and **COLICA Pictorum**.

M. Navier has lately discovered that the liver of sulphur, and particularly liver of sulphur of Mars, is an excellent antidote against the poison of lead; and he advises patients labouring under its pernicious effects to drink largely of acidulated liquors, to make afterwards the liver of sulphur the principal part of the cure, and to finish the cure with gentle purgatives.

The Dutch have been charged with correcting the more offensive expressed oils, as that of rape seed, so as to substitute them for oil olive or oil of almonds, by impregnating them with lead: in order to detect this abuse, mix a little of the suspected oil with a solution of orpiment made in lime-water: on shaking them together, and suffering them to rest, the oil, if it has any saturnine taint, will appear of an orange-red colour: if pure, of a pale yellowish. The lead is discovered in wines by the same sulphureous solution, which changes the colour of wines impregnated with this metal to a brownish red or a blackish hue. However, the various preparations of lead are applied externally with safety and great benefit, on account of its sedative, drying, and repellent qualities. The vinegar and fugar of lead, and all the ointments and plasters which contain ceruse, minium, or litharge, eminently possess these qualities. See the following articles and references.

For the laws relating to lead, and the stealing of it, see 27 Ed. III. stat. 2. c. 1. 3. 15. 38 Edw. III. stat. 1. c. 6. 4 Geo. II. c. 32. 29 Geo. II. c. 30. See **LARCENY**, **LEAD**, *Black*. See **PLUMBAGO**.

Black lead in fine powder may be readily mixed with melted sulphur, and though the compound remains fluid enough to be poured into moulds, it looks nearly like the coarser sorts of black lead itself. This was probably the method by which prince Rupert is said to have made black lead run like a metal in a mould, so as to serve for black lead again. Birch's Hist. Royal Soc. vol. iii.

The German black-lead pencils, and those which are hawked about among us, are prepared in this manner: their melting or softening, when held in a candle, or applied to a red-hot iron, and yielding a blueish flame, with a strong smell like that of brimstone, discovers their composition. Pencils of this kind are hard and brittle, and cut or scratch the paper or wood instead of marking them. The true English pencils are formed of black lead alone, sawed into slips, which are fitted into a groove made of the softest wood, as cedar, and another slip of wood glued over them. These pencils, however, are of different quality, on account of different sorts of the mineral being fraudulently joined together in one pencil, the fore-part being commonly pretty good, and the rest of an inferior kind. To avoid these inconveniences, some take the finer pieces of black lead itself, which they saw into slips, and fix for use in port-crayons. Lewis's Commerce of Arts, p. 328.

By our laws, entering mines of black lead, with intent to steal it, is made felony. See 25 Geo. II. c. 10. See **LARCENY**.

LEAD, for the *manufacture of*, see **PLUMBERY**.

There are various preparations of lead, serving for various purposes, some of which are now disused, and others, under one form and name, or another, still continued.

LEAD, Balsam of, an external medicine, formerly famed for its effects in old and sharp ulcers. It is made by mixing one ounce of sugar of lead with two of oil of turpentine, and letting this mixture in a sand-heat till the salt is dissolved. By this means the oil acquires a red colour, and is called balsam of lead.

LEAD, Burnt, plumbum ustum, is a chemical preparation used in medicine, made of plates of lead, melted in a pot with sulphur, and reduced by fire into a brown powder.

Lead continued in fusion and stirred, so that fresh surfaces may be exposed to the air, will gradually change into a powdery dusky-coloured calx, bearing this name.

Burnt lead is only intended for external use. It has the same virtues ascribed to it, in ointments and plasters, as litharge or minium. Mixed into an unguent with lard alone, it makes a good ointment for the piles.

LEAD, Butter of, is a kind of liquid unguent made of vinegar and lead, incorporated with roseate oil, and recommended for the cure of tetters. It is called *butyrum saturni*.

LEAD, Calined, or calx of lead. See CALX, CERUSSE, GLASS of Lead, LITHARGE, MASSICOT, MINIUM, &c. and *All'ys of LEAD*, *supra*.

LEAD, Casting of. See CASTING.

LEAD, Cerate of Super-acetate, Ceratum plumbi super-acetatis, the "*Unguentum cerussæ acetatæ*" of P. L. 1787, is prepared in the following manner: Take of super-acetate of lead two drachms, white wax, two ounces, and olive oil, half a pint. Dissolve the wax in seven fluid-ounces of oil, then gradually add to it the super-acetate of lead, separately rubbed down with the remaining oil, and stir the mixture with a wooden slice, until the whole has united.

LEAD, Compound cerate of. See CERATUM lithargyri acetati compositum.

LEAD, Cohesion of. See COHESION.

LEAD Dust is a preparation used by the potters; made by throwing charcoal dust into melted lead, and stirring them a long time together: to separate the coal again, they only wash it in water, and dry it afresh. Its use is, to give a varnish and gloss to their works.

LEAD, Extract of, or Saturn, is prepared by simmering together as many pounds of the litharge of gold as quarts of vinegar for an hour and a quarter, and often stirring them; then taking it from the fire, and as soon as it is cool enough, pouring the clear liquor into bottles to be kept for use. If this liquor be made into the common consistence of an extract, it must boil yet longer after its separation from the mass, and will acquire a reddish colour. This is Goulard's extract (see LEAD, *supra*), and the basis of all his preparations of lead. It evidently differs in no respect from sugar of lead, and vinegar of litharge, but in the degree of concentration. The only circumstance in which the extract seems to have the advantage of sugar of lead, appears to be in the greater quantity of the acetous acid contained in it, which proves an excellent assistant in many cases, and the sugar of lead, when once crystallized, cannot be brought back to that state of solution in vinegar in which it was before; yet where a large quantity of watery menstruum is added, as in Mr. Goulard's saturnine water, it is as well to make a solution of sugar of lead in the water, and add the vinegar afterwards, as to mix them both together in the form of extract. Aikin's Obs. on the external Use of Preparations of Lead, &c. p. 2. See VINEGAR of Lead.

In the London Pharmacopœia of 1787, this was denominated "*Aqua lithargyri acetati*;" and in the last edition it is called "*Liquor plumbi acetatis*," or "solution of acetate

of lead," and it is directed to be prepared by mixing two pounds four ounces of semi-vitreous oxyd of lead, with a gallon of acetic acid, and boiling down to six pints, constantly stirring; then setting it by, that the feculencies may subside, and straining. This is a dense liquor, of a deep brown colour, and consists of a saturated solution of subacetate of lead. It was restored in the last Pharmacopœia, in consequence of the celebrity it had obtained under the name of "Goulard's Extract." The "*Aqua lithargyri acetati composita*" of P. L. 1787, called in the last edition "*Liquor plumbi acetatis diluti*," or "diluted solution of acetate of lead," is prepared by mixing a drachm of solution of acetate of lead, a pint of distilled water, and a fl i-drachm of weak spirit. When this mixture is made, even with distilled water, some precipitation takes place; and when, as is more common, ordinary water, containing any muriates or sulphates, is used, this is much more abundant from double decomposition, and gives the liquor a milky appearance when diffused through it. To this it owes its common name of "white wash."

LEAD, Glass of. See GLASS of Lead.

LEAD, Magillery of, is the calx of lead purified and subtilized. It is made of lead dissolved in aquafortis, pouring filtrated salt water into it; whence results a magillery extremely white, which, when softened by several lotions, is mixed with pomatums for the face and complexion.

LEAD Mine. See MINING.

LEAD, Mock, a name given to a glittering substance found in lead-mines. See GALENA inanis, and BLINDE.

LEAD, Native. See LEAD, *supra*.

LEAD, Ointments of, Preparations of. See UNGUENT.

LEAD Plaster. See EMPLASTRUM Commune.

LEAD Pipes, Manufacture of. The common method used for making lead pipes, consists in casting the lead upon a smooth steel mandril placed in a mould, also of metal, to form the outside. These pieces are about 18 inches long. They are afterwards joined together by a process, called *lining*.

A very great improvement has been made in the manufacture of lead pipes, by drawing them in a manner similar to wire. The lead to form the pipe is cast upon a mandril of the diameter of the inside the pipe, but of such a thickness as to equal the whole pipe in weight: it is then fattened upon one end of a cylindric steel mandril, and the lead is pulled through different sized holes, till the pipe is of sufficient length and thickness. These pipes can be drawn to the length of eight or ten feet. The power required, however, is very great, which is one objection to the method. They are also liable to flaws; for, if the casting happen to be imperfect, the imperfection is much increased and extended by the process of drawing.

This manufacture has been much improved by passing the lead upon the mandril, through grooved rollers of different sizes, following each other in succession. The power required is much less than that required for drawing; and the pipes are said to be superior in other respects. For a more particular account of this manufacture, see LEAD PIPES.

LEAD, Red, a preparation of mineral lead calcined and rubified; used by painters, potters, and surgeons. See MINIUM, and Oxyds of LEAD.

LEAD, Salt or Sugar of, Saccharum saturni, Superacetatæ plumbi, superacetate of lead, is an essential salt of vinegar, incorporated with the proper substance of lead, or ceruss, dissolved in spirit of vinegar. See SACCHARUM Saturni, and LEAD, *supra*.

Leather

LEATHER, in *Commerce*, the skins of several sorts of beasts dressed and prepared for the use of various manufacturers, whose business is to make them up, according to their different employments. The butcher and others, who flay them off the carcases, dispose of them raw or salted to the tanner and tawer; they to the shamoy, morocco, and other kind of leather-dressers, who prepare them according to their respective arts, in order to vent them among the curriers and leather-cutters, glovers, harness-makers, coach-makers, saddlers, breeches-makers, gilt-leather-makers, chair-makers, shoe-makers, book-binders, and all in any way concerned in the article of leather.

Leather has divers names according to the state wherein it is, and according to the different kinds of skins of which it is prepared, and its peculiar qualities when so prepared.

1. The skin is raw as it comes off the animal. 2. Some are salted with sea-salt and alum, or with natron, which is a species of salt-petre, or white salt-wort, to prevent corruption in keeping, or sending to distant tanneries during hot seasons.

Skins dried with the hair on, are commonly those of oxen and cows, or buffaloes, either tame or wild. Most of those in France come from foreign countries. The places which furnish the largest quantity, are Peru, the isle of St. Domingo, Barbary, Cape Verde Isles, the river Senegal in Africa, Muscovy, Ireland, the island of Cuba. Those of this latter place are the most esteemed; they are called Havannah skins, from the name of the capital city of that island, whither they are carried in order to be sent to Spain, and from thence into other parts of Europe. After these skins are stripped of their hair, they are sold to the tanners. See CURRYING, TANNING, and SKINS.

The three principal assortments of leather are tanned or tawed, and oil and alum leather, all which are dressed in some yards.

The art of dressing leather in oil consists in first soaking the skins; then throwing them into the lime-pit; and when they are taken hence, pulling them and delivering them to the friezer; they are then struck with the oil, and sent to the mill; when they are milled sufficiently, they are thrown into the ditch to be scoured, and by some scudded, and afterwards hung upon the hooks to dry. When they have been weighed and marked by the proper officers, in order to fix the excise duty, they are fit for sale. The sorts of skins dressed in oil are those of deer, sheep, and lambs, and some few of goat, and the oil used for this purpose is Newfoundland, or cod's liver oil. The alum leather-dressers' art consists in properly soaking, liming, wringing, (an operation sometimes omitted,) and striking them in a liquor composed of water, salt, and alum, and then drying them properly. The sorts of skins dressed in alum are those of sheep and lambs, and a large quantity of kid. *Posleth. Dict. Com. art. Leather.*

There are several statutes relating to leather; the 27

Hen. VIII. c. 14. directs packers to be appointed for leather to be transported: but the 18 Eliz. c. 9. prohibits the shipping of leather on penalty of forfeiture, &c. Though by 20 Car. c. 5. transportation of leather was allowed to Scotland, Ireland, or any foreign countries paying a custom or duty; which statute was continued by divers subsequent acts.

No person shall ingross leather to sell again, under the penalty of forfeiture. None but tanners are to buy any rough hides of leather, or calves' skins in the hair, on pain of forfeiture; and no person shall forestall hides, under the penalty of 6s. 8d. a hide. Leather not sufficiently tanned is to be forfeited. In London, the lord mayor and aldermen are to appoint and swear searchers and sealers of leather out of the company of cordwainers, &c. and also triers of the sufficiency of leather; and the same is to be done by mayors, &c. in other towns and corporations; and searchers allowing insufficient leather, incur a forfeiture of 40s. Shoemakers making shoes or boots of insufficient leather are liable to forfeit for every pair 3s. 4d. and the value thereof. (1 Jac. I. c. 22.) Red tanned leather is to be brought into open leather markets, and searched and sealed before it be exposed to sale, and on sale is to be registered, or shall be forfeited; and contracts for sale otherwise to be void. (13 & 14 Car. II. c. 7.) Hides of leather are adjudged the ware and manufacture of the currier, and subject to search, &c. All persons dealing in leather may buy tanned leather, searched in open market, and any person may buy or sell leather, hides, or skins, by weight. 1 W. & M. c. 33.

The first statute concerning leather, which it is necessary for us to refer to in this article, is the 1 Jac. c. 22, which reduces all preceding acts relating to that commodity into one; and therefore to this we shall have a retrospect in the progress of this article; premising that all forfeitures by this act, not otherwise specially directed, shall be divided, one-third to the king, one-third to him that shall sue, and one-third to the city, town, or lord of the liberty. By 9 Ann. c. 11. any two justices near the place where the forfeitures are incurred, or offence committed, may hear and determine the same. All forfeitures, by the act of 13 & 14 Car. II. c. 7. shall be recovered in any court at Westminster, or in any court of record in the city, &c. where the offence shall be committed; to be distributed half to the king, and half to the informer. By 39 & 40 Geo. III. c. 66. it is enacted that proper places and times for inspecting all raw hides and skins of cattle, sheep, horses, and hogs, shall be fixed by the mayor, bailiff, or head-officer of any city, town corporate, borough, or market-town, or any two magistrates acting for the same, or any two justices acting for the division within or nearest to such city, &c. The manner of appointing inspectors is also prescribed by the said acts. And by the same, butchers, &c. who are chargeable with wilfully or carelessly injuring hides, so as to make them less valuable, are liable to penalties, not exceeding 5s. (41 Geo. III.) nor less than 1s. for the raw hide of every ox,

bull, cow, or heifer, &c.; and not exceeding 2s. 6d. (41 Geo. III.) nor less than 6d. for the skin of every calf; and not exceeding 2s. 6d. (41 Geo. III.) nor less than 1s. for the hide of every horse, mare, or gelding; and not exceeding 6d. nor less than 3d. for the hide of every hog, pig, sheep, or lamb. Inspectors are required to take a prescribed oath, and are allowed certain fees for examining and inspecting hides, &c. (See also 43 Geo. III. c. 106.) These inspectors may impose penalties for damaging hides, &c.; which penalties shall be recovered before a justice, one-half of which, by 41 Geo. III. c. 53. shall be given to the inspector, and the other half applied to the purpose of better carrying on the objects of these acts. By the above-cited acts, 39 & 40 Geo. III. c. 66, the inspectors of raw hides shall provide proper stamps, and stamp the hides, not damaged or otherwise; and seize such hides or skins as have been damaged, and sell the same, provided the penalties be not paid in less than 48 hours after such seizure. Butchers or others neglecting to bring hides to be marked, shall forfeit not exceeding 5l. nor less than 40s. for every such hide. The regulations of this act shall extend to all hides found in Great Britain. (41 Geo. III. c. 53.) All disputes shall be settled by any five impartial and respectable persons concerned in the manufacture of leather, summoned by a magistrate, before whom such dispute shall be brought. All penalties and forfeitures shall be recovered before one justice or magistrate of any city, town, or place, where the offence shall be committed, upon conviction, confession, or the oath of one witness, and levied by distress; and for want of sufficient distress, the offending party shall be committed by such justice or magistrate to the common gaol or house of correction, for a time not exceeding one month. All penalties and forfeitures, not otherwise disposed of, shall go, half to the informer, and half to the execution of the purposes of the act. Persons aggrieved may appeal to the next sessions. (39 & 40 Geo. III. c. 66.) By the same and 41 Geo. III. c. 53. informations for offences against this act for wilfully or carelessly gashing raw hides, shall be laid within three days after the commission of the offence; and for any other offence within 14 days after the offence committed. By 43 Geo. III. c. 106. the provisions of 39 & 40 Geo. III. c. 66. and 41 Geo. III. c. 53. are extended to London, Westminster, and Southwark, and to all places within fifteen miles of the Royal Exchange. All raw hides within five miles of the Royal Exchange shall be brought to Leadenhall market, and the skins of sheep and lambs to one of the three sheep-skin markets in Southwark, the Whitechapel market, or the market at Wood's Clove. Proper places and hours for inspection are to be appointed within three months after the passing of this act. For the market at Leadenhall, eight inspectors are to be appointed; four from the company of butchers, two by the company of curriers, and two by the company of cordwainers; and besides, there shall be appointed four inspectors for the sheep market at Wood's Clove, two for Southwark, and two for the market of Whitechapel. One half of the inspectors at each of the three last-mentioned markets to be appointed by the company of butchers, and the other half at each of such markets in equal proportions by the companies of curriers and cordwainers. Provision is made for increasing their number and regulating their attendance. Inspectors for Leadenhall market are required to attend on the usual market days, from six in the morning till five in the afternoon, from the 25th of March to the 29th of September; and from seven in the morning until four in the afternoon, from the 30th of September till the 24th of March.

The distribution of fines and fees is prescribed, so that one-

half shall be equally divided between the inspectors, acting at the respective markets, and the remaining half-part shall be paid weekly to the arbitrator of the market, in respect to which they are received, and paid monthly by the said arbitrators to the respective persons appointed by the courts of assistants to receive the same. There is a penalty for impeding inspectors, not exceeding 5l. nor less than 10s. for each offence, and also a penalty not exceeding 20l. on inspectors receiving, and persons offering bribes. Salesmen are required to deliver an account of hides or skins sold, under a penalty for every offence of 10l. The lord-mayor of London is empowered to increase the fees of the inspectors, under the representation of the courts of assistants of the companies concerned, to any sum not exceeding 1d. for every hide, $\frac{1}{2}$ d. for every calf-skin, hog-skin, or pig-skin, and $\frac{1}{4}$ d. for every sheep or lamb-skin. The respective courts of assistants are required to appoint annually four arbitrators, to settle disputes arising in any of the markets above-mentioned; and these arbitrators are empowered to fine inspectors, and also butchers and salesmen, for frivolous decisions and exorbitant impositions. Inspectors and arbitrators are liable to be dismissed for misconduct in their respective offices, or to a fine not exceeding 5l. nor less than 10s. Buyers and sellers of untanned hides or skins are liable to a forfeiture not exceeding 20s. nor less than 5s. for every hide; and not exceeding 5s. nor less than 1s. for every skin of hogs, pigs, or calves; and not exceeding 1s. nor less than 6d. for every sheep or lamb-skin. The treasurers are appointed by the respective courts of assistants to receive the sums collected by the arbitrators; one-half of which shall be paid to the treasurer appointed by the company of butchers, one-fourth to the officer of the company of curriers, and one-fourth to the officer of the company of cordwainers; which sums shall first of all be applied for the execution of the acts, and to the use of the poor of the said companies.

For particular regulations concerning *tanners* and *curriers* of hides, see these articles respectively. The mayor and aldermen of London (on pain of 40l. for every year they make default, half to the king and half to him that shall sue) shall yearly appoint eight freemen of some of the companies of cordwainers, curriers, saddlers or girdlers, of whom one shall be a sealer, and keep a seal for the sealing of leather; they shall be sworn to do their office truly; and they shall search and view all tanned leather brought to market, whether it is thoroughly tanned and dried: and if it is, shall seal the same. Four of these officers shall be changed every year; no officer shall be continued above two years together, nor be re-elected till after the end of three years, on pain of 10l. a month. A similar regulation extends to other places. The wardens of the curriers shall search and seal curried leather, for which they are entitled to fees, to be paid by the currier; on pain of forfeiture for every hide not searched and sealed, 6s. 8d. If any searcher or sealer shall neglect his office or misbehave, he shall forfeit 40s.: if he shall take a bribe, or exact a fee not appointed, he shall forfeit 20l.; and if he shall refuse to execute his office, he shall forfeit 10l. If any person shall hinder the searcher in the execution of his office, he shall forfeit 5l. (1 Jac. c. 22.) The mayor of London (on pain of 5l. half to the king, and half to him that shall sue) shall, within six days after notice given of any seizure of any leather, red and unwrought, appoint six triers, two of the cordwainers, two of the curriers, and two of the tanners, using Leadenhall market, who, upon their oaths taken before him, shall, on the second or third market-day for leather, try the same, whether it be sufficient or not. The same regulation extends to other places. Triers not doing their duty shall forfeit 5l. The offering for sale of unsearched

and unsealed leather incurs a forfeiture of the same, or its value, and for every hide or piece 6*s.* 8*d.*; and for every dozen of calves' skins, 3*s.* 4*d.*; but no person shall incur any penalty for selling or buying any sheep-skins, unsearched or unsealed. (1 Jac. c. 22. 4 Jac. c. 6.) All red tanned leather shall be bought only in the open fair or market, and not in any house, yard, shop, or other place, on pain of forfeiting the same, or its value, and rendering the contract void: and such leather shall be searched and sealed before sale, and on sale shall be registered, on pain of forfeiting the same, or its value. (13 & 14 Car. II. c. 7.) Searchers and sealers shall keep a register of all bargains made for leather, during the fair or market, with the prices; taking for searching, sealing, and registering of every ten hides, or butts, of the seller 2*d.*, and so in proportion; and for every six dozen of calves'-skins, or sheep-skins, 2*d.*: and of the buyer after the same rate. Red tanned leather, brought into London, or within three miles of it, shall be brought to Leadenhall, to be viewed and registered by the searchers, with half such fees to be paid for tanned leather bought out of London, or within three miles, and searched and sealed before it be brought within the city; on pain that every person housing, or not bringing his leather to Leadenhall, shall forfeit for every hide or skin 6*s.* 8*d.* No person shall buy any tanned leather, unwrought, but who shall work the same into wares, on pain of forfeiting the same, or value. (1 Jac. c. 22.) But by 12 Geo. II. c. 25, all persons who deal or work in leather may buy all sorts of tanned leather in open fair or market, whether curried or uncurried, being first searched and sealed, and may cut and sell the same in any small pieces in their open shops. (See also 1 W. sess. 1. c. 33.) Within London, or within three miles, no person shall sell any wares appertaining to the mystery of any artificer cutting leather, but only in open shop, common fair, or market, whereby the wardens may have search thereof: on pain of forfeiting the same, and also 10*s.* 1 Jac. c. 22.

No shoemaker shall make any boots or shoes, or any part of them, except of leather, well and truly tanned and curried, or of leather well and truly tanned only; nor put into any part of any shoes or boots, any leather made of a sheep-skin, bull-hide, or horse-hide, &c. &c., on pain of forfeiting for every pair of shoes or boots 3*s.* 4*d.*, and the value. And if any artificer using leather do make any wares of any tanned leather insufficiently tanned, or of tanned and curried leather, not sufficiently tanned and curried, he shall forfeit the same, and value. If any shoemaker or cobbler within London, or three miles of it, shall put any tanned leather into any boots or shoes, or other things made of tanned leather, which shall not be well and perfectly tanned, or do put any curried leather into boots or shoes, or any things made of leather, which shall not be sufficiently tanned and curried, and also sealed; he shall forfeit the same and value. 1 Jac. c. 22.

All sorts of leather and skin, tanned or dressed, may be exported. 20 Car. II. c. 5. 9 Ann. c. 6.

By 43 Geo. III. c. 69, a duty is laid upon all hides and skins, vellum and parchment, imported; and drawbacks allowed on the exportation of them. Other duties are also imposed by 49 Geo. III. c. 98. for which we refer to the act, sched. A. After the duty on importation shall be paid, the officers of the customs shall cause every hide or skin to be marked, to denote the payment of the duty. (9 Anne. c. 11.) But by 15 Geo. III. c. 35, raw or undressed goat-skins may be imported for five years, duty free; and this act was made perpetual by 31 Geo. III. c. 43. The several duties for and upon all hides and skins, and parts and

pieces of hides and skins, tanned, tawed, or dressed, to be paid by the tanners, tawers, and dressers of hides and skins respectively, and the duties upon vellum and parchment, to be paid by the respective makers thereof; and certain drawbacks are allowed on the exportation thereof. By tanned hides or skins, or pieces thereof, are meant only such as are tanned in wooze, made of the bark of trees, or shumack; and by hides and skins, dressed in oil, are meant such as are made into leather in oil, or with any materials, of which the chief ingredient shall be oil; and by tawed hides or skins, are meant such as are dressed or made into leather, in alum and salt, or meal, or other ingredients properly used by tawers of white leather. 9 Ann. c. 11. s. 3.

By 43 Geo. III. c. 69, every tanner shall take out a licence annually, for which he shall pay, if within the bills of mortality, 5*l.*, elsewhere 2*l.* 10*s.*, on pain of 30*l.* (24 Geo. III. c. 41. Sess. 2. § 1.) And every tawer shall take out a licence annually, for which he shall pay 1*l.* on the penalty of 10*l.* And every dresser of hides in oil shall take out a licence annually, for which he shall pay 2*l.* on the penalty of 20*l.* And every currier shall take out a licence annually, for which he shall pay 2*l.* on the penalty of 20*l.* And every maker of vellum or parchment shall take out a licence annually, for which he shall pay 1*l.* on the penalty of 10*l.* And every person who shall take out such licences shall renew them annually, ten days before their expiration, on the penalties above stated. Collar-makers, gloves, bridle-cutters and others, who dress skins or hides, or pieces thereof, in oil, alum, and salt, or meal, or other ingredients, and who cut and make the same into wares, shall be accounted tawers, or dressers. (2 Ann. c. 11. § 28.) Any hide or skin, which hath once paid the duty, shall not be charged under any other denomination (9 Ann. c. 11. § 3.) The commissioners of these duties, appointed by the commissioners of the treasury, shall have the same power as the commissioners of excise. Tanners, tawers, curriers, or dressers of hides or skins, and makers of vellum or parchment, are required to give notice in writing to the officer, of their names and places of abode, and of their tan-houses, yards, work-houses, mills, or other places where they intend to tan, taw, or dress hides or skins, or make vellum or parchment, before they use the same; on pain of 50*l.* Those who use such places without entry of them, shall forfeit 20*l.*, and the goods found in them, or their value, shall also be forfeited. The officers, at all seasonable hours, shall enter and survey these places, and if the owner or occupier refuse them entrance, he shall forfeit 10*l.* And if any hide or skin, tanned, tawed, or dressed in oil, be found in any place not entered, without a stamp denoting that the duty has been charged, the same shall be forfeited and seized; and the persons in whose possession it shall have been found, shall for each offence forfeit 100*l.* (41 Geo. III. c. 91. § 10.) Tanners and others shall give two days notice to the proper officers of the removal of goods to the drying place, that an account of them may be taken; and before they are carried away from the drying place, two days notice shall be given; and they shall be entered with the officer with respect to their number and quality, and verified on oath before a justice of peace, collector or supervisor; nor shall they be removed, till the duty be first charged, entered and marked. The penalty for neglect is 20*l.* and forfeiture of the goods, or their value. Concealment of any hide or skin, vellum or parchment, in order to avoid the duty, incurs a forfeiture of 20*l.* and the goods or their value. If any tanner or other person shall shave any hide or calf-skin, before the same be thoroughly tanned, so as to impair it and diminish the duty, the same or its value shall be forfeited. Tanners or other such person shall keep

jult scales and weights ; and the penalty for neglect or not allowing the use of them, shall be a forfeiture of 50*l*. The use of false scales incurs a forfeiture of 100*l*. (10 Geo. III. c. 44. 28 Geo. III. c. 37.) Cheating or obstructing officers subjects to a forfeiture of 100*l*. (26 Geo. III. c. 77.) When the duties are ascertained, the officer shall enter them in a book, and return them to the commissioners, or a person appointed by them ; and when the duty is settled, the officer shall cause every hide or skin, and every piece of both, and all vellum and parchment to be marked. And if the goods be removed before the duty is charged, and they are marked, the penalty is a forfeiture of 50*l*. and the said goods ; and any person counterfeiting the stamps, or knowingly selling any of the said goods with a counterfeit stamp, is chargeable with felony without benefit of clergy. (9 Ann. c. 11. 5 Geo. II. c. 3. 33 Geo. III. c. 54.) Stamped and unstamped goods shall be kept separate, on pain of 10*l*. (5 Geo. c. 2.) And those that have been stamped shall not be removed for 24 hours after stamping, &c. under a forfeit-

ure of 20*l*. (5 Geo. III. c. 43.) Scales and weights shall be kept for reweighing them, and assistance given to the officer, on pain of 50*l*. Persons within the bills of mortality shall pay off the duties within 14 days to the commissioners, and in other places in six weeks, after the goods have been marked. (9 Ann. c. 11.) Those who do not pay in this manner shall forfeit double duty ; and they shall not be delivered out till the duty be paid, on pain of double value. Every tanner, and other such person, shall balance their accounts with the officers once in three months, on pain of 50*l*. Any two justices residing near the premises may hear and determine offences, and order the penalties to be levied by distress and sale, if not redeemed in six days.

Foreign manufactured gloves imported shall be forfeited, and may be searched for and seized by any officer of the customs or excise ; and every person importing or vending the same, shall also forfeit 200*l*. with double costs. 6 Geo. III. c. 19.

Lighthouse

LIGHT-HOUSE, in the *Marine*, is a building or watch-tower erected upon the sea-shore, to serve as a landmark to mariners in the night, to avoid any rocks or other dangers. The light-house is generally a high tower, having at the top an apartment called the lantern, with windows on all sides, to exhibit the light made within it by the flame of an open fire, or by lamps or candles. It is frequently of service to navigation, to erect light-houses upon insulated rocks rising from the sea, to warn ships of their approach to such rocks. Of this kind are the Eddystone rocks off Plymouth, and the Bell rock at the mouth of the Forth in Scotland. In these situations, the heavy swell of the sea, when agitated by a storm, strikes with such force against the building, as to require every precaution to secure them from being overthrown by the continued action of so powerful an enemy. The Eddystone rocks being the most celebrated, as well from their peculiarly exposed situation, as from the great ingenuity displayed in the construction of the light-houses erected at different periods upon them, renders them deserving of particular description. The history of the different erections has been already given under the head of EDDYSTONE. We here intend describing the construction of each, which will be a summary of all the different kinds of light-houses of wood or stone.

Mr. Winstanley's light-house was begun upon the Eddystone rock in 1696, and was more than four years in the erection, from the many interruptions of the wind, which from some quarters causes the sea to break over these rocks with such violence, as to prevent the possibility of landing upon them, though the sea around is very quiet. This is occasioned by the rocks being open to the swell from the Great Atlantic ocean, or from the Bay of Biscay, in all the south-western points of the compass; and is increased by the form and position of the rocks, which have

a regular slope to the south-west from the deep sea to the rock upon which the house is erected, and which, therefore, receives the uncontrouled fury of these seas, meeting no other object to break upon, and the effect of so great an extent of water, caused by the hard S.W. winds, continues for many days, though succeeded by a calm, and breaks frightfully upon Eddystone. When there is no wind, and the surface of the sea appears smooth, Mr. Winstanley's light-house appears, from an engraved plate of it, published by himself, to have been a stone tower with 12 sides, rising 44 feet above the highest point of the rock, which is inclined so as to be 10 feet lower on the opposite side of the house. The tower was 24 feet in diameter. At the top were a balustrade and platform: upon this eight pillars were erected, and supported a dome of the same diameter as the tower. From the top of this arose a smaller octagonal tower, 15 feet in diameter and seven in height; and upon this was the lantern 10 feet in diameter, and 12 high, containing the lights. It had a gallery or balcony surrounding it, to give access to the outside of the windows. The whole was surmounted by a fanciful iron work with a vane. The entry was by a door at the bottom, which was solid stone, except the aperture for the staircase, 12 feet in height. Above this were three floors, the lowest being the store-room, the next the state-room, and the third the kitchen. These occupied the height up to the level of the platform, or open gallery above-mentioned. The dome above this contained the lodging-room, and the octagon above it the attending or look-out room, immediately beneath the lantern. This edifice was, as before-mentioned, more than four years in erecting. The first summer (for it is only in this season the rock is accessible) was spent in making 12 holes in the rock, and fastening 12 great irons to hold the future work. In the second year, a solid pillar 14 feet diameter, and 12 feet

high, was built as a core or centre for the building. The third year the pillar was increased to 16 feet diameter, and all the work was raised, which to the vane was at that time 80 feet. The workmen lodged in the house soon after Midsummer, but were by bad weather imprisoned 11 days before a boat could relieve them. A light was exhibited on the 14th of Nov. 1698. But finding that the sea frequently broke over the lantern, in the fourth year the whole building was encompassed with a new work of four feet in thickness, made solid for near 20 feet high, and the lantern was raised 40 feet higher than at first, making it 90 feet to the top of the cupola of the lantern, above which the vane rose 22 feet. "Yet after all," Mr. Winstanley says, "the sea in storms flies in appearance 100 feet above the vane, and at times doth cover half the side of the house and the lantern, as if it were under water." The joints of the additional stone work of the fourth year, appear to have been covered with an iron or copper hoop encompassing the building, to prevent the sea washing out the mortar. The building withstood the wash of the sea only till the year 1703, when the inventor, being at Plymouth to superintend some repairs of the building, went off to it on some of his friends intimating the danger of the building, from a storm which seemed coming on. He expressed a wish that he might be present in the most violent storm which ever blew, to observe its effect on the structure. In this he was too amply gratified, for on the 26th of November a violent storm arose, and the next morning no vestige of the light-house remained, except some of the irons which were fastened in the rock, and a piece of iron chain, which was jambed fast into a chink of the rock, and nothing was ever afterwards found. Thus perished the first light-house with its ingenious, but unfortunate, builder. A West Indian ship was lost on the rocks soon after the light-house was overthrown. This circumstance, and the great utility of the light while exhibited, stimulated the Board of Trinity house, who had the management of the building, to erect another, and an act of parliament, of the 4th of queen Anne, was passed in 1706, to enable the Board of Trinity house to raise duties on ships to rebuild it, of which they granted a lease of 99 years to Capt. Lovel, as he engaged to build and maintain the house. In July 1706, the work was begun under the direction of Mr. John Rudyerd, who was at that time a silk mercer on Ludgate hill, London, but who appears to have possessed much ingenuity and mental resource. He, like Mr. Winstanley, published a print drawn by B. Lens, and engraved by J. Sturt, which informs us, that it was a conical frustum of wood, formed of 71 upright beams, united together by being bolted to circular kirbs of wood withinside, upon which kirbs the floors were framed. It, in some degree, resembled an immense conical cask, but without hoops: the diameter at the base was 23 feet, at the top 15 feet, and its altitude, from the highest point of the rock to the top of the upright, was 62 feet. At the top of the building was a balcony, surrounded by a railing, and in the centre of the area thus formed the lantern was situated. It had windows on all sides, and was of an octagonal figure, 10 feet in diameter, and 13 high, surmounted by a dome with a simple ball at top, instead of the fanciful iron work which ornamented the first edifice. Mr. Rudyerd, from principles totally different from those of his predecessor, made his building quite plain, without the least projection or ornament on which the water could act when dashing against it; and he omitted no precaution of uniting all the parts together, and fastening the whole to the rock. As the surface of the rock was naturally inclined, and the whole building would have had a tendency to slide down it, if merely placed upon it, as Mr. Winstanley's was, Mr. Rudyerd wished to

reduce its surface into level steps, upon which each timber would have a horizontal bearing; but finding this to be the most difficult of the whole undertaking, it was imperfectly executed, only five steps being cut, and these did not take out all the inclined surface; however, it was sufficient for the purpose.

The building was filled up quite solid for 19 feet from the lowest point of the rock, and, excepting the well for the stair-case, was solid to the height of 37 feet. The solid was formed of three beds of moor stone, with strong floorings of timbers between each bed, to unite them with the external uprights. The lower bed contained five courses of stone, and was five feet thick; the second was the same, and the third was four feet thick, containing four courses. The whole erection, in addition to the weight of this stone, which was about 280 tons, was secured to the rock by 36 iron cramps, part of them arranged in a circle about a foot within the external uprights, and the remainder, which were smaller cramps, in an interior circle three feet distant from the former, to hold down the floors of timber which had the stone beds between them. In the centre of the building a strong mast was erected, secured by two cramps to the rock at the bottom, and rising above the solid to the height of 48 feet, being united to the framing of each floor it passed through, and thus forming a central axis to strengthen the whole. The house above the solid contained four apartments, the lower being the store room, the next the slate room, the third the bed chamber, and the fourth the kitchen, immediately beneath the lantern. In the manner of fixing the irons to the rock, upon the duration of which the security of the whole work depended, Mr. Rudyerd succeeded most admirably. The holes in the rock were made by drilling two holes rather diverging from each other, so that they would be an inch more asunder at 15 or 16 inches depth, than on the surface of the rock. A third hole being drilled between these two, and the three being broken into one, formed a hole larger at the bottom than the top. The iron cramp was formed of two pieces, which, when laid together, were of the shape of the hole, but when separated, one was larger at the bottom than the top, and the other smallest at the bottom; therefore the former being first put down into the hole, and the latter driven in by the side of it, wedged it fast, and both being united by the same bolts which attached them to the timbers, rendered it impossible to draw them out. They were put in their places hot, and a quantity of melted tallow being first poured into the hole, when the hot irons were put down the tallow ran over on all sides, and thus certainly filled up all cavities. A quantity of coarse pewter, made red-hot, was now poured into the cavity round the irons, and, being a heavier fluid, displaced the tallow, and filled the space round them completely, the tallow effectually preventing the entrance of the sea water into the most minute cavities. This method is worthy of record, as it may be applied to many other useful purposes. Mr. Rudyerd, as before-mentioned, began his operations in July 1706; in July 1708, he had so far completed it as to exhibit a temporary light; and the whole was completed in the following year. This building had some repairs of its timbers in 1723, and again in 1744, when a violent storm had carried away a great number of the upright timbers: but it shewed itself, in the course of 49 years, to be a very excellent construction of its kind, and only liable to destruction from the perishable nature of its materials, or the catastrophe which awaited it on the night of the 2d of Dec. 1755, when one of the attendants, entering the lantern to snuff the candles, found it in flames, and, notwithstanding every exertion, the fire communicated to the uprights, and burned downwards. The unfortunate men de-

scended from room to room as the fire increased, and were at last obliged to take refuge, from the fall of burning timbers, in a cavity of the rock, from which they were relieved by a boat the next morning. The wind, unfortunately, blew from the east, and though it caused such a swell as to prevent landing, did not break on the house so as to extinguish the fire; and thus, in a few days, the whole was destroyed, except the iron cramps in the rock.

It is remarkable, that whilst one of the light keepers, at the commencement of the fire, was looking up at the fire in the cupola of the lantern, a body of melted lead showered down upon him, and he declared a quantity had passed down his throat into his stomach. He lived only 12 days after being taken on shore; and on opening the body, a mass of lead was taken from the stomach, weighing more than seven ounces. The curious fact, of his having 12 days survived so alarming an accident, was communicated by his attendant surgeon, Dr. Spry, to the Royal Society, but the circumstance appeared so improbable, that it did not, at first, meet that credit, which future experiments on animals proved he was entitled to.

On the news of the fire reaching London, the proprietors (for by the sale of Capt. Lovel's original lease, the property of the light-house was now in many hands,) immediately took measures to restore it, and appointed one of their members, Mr. Rob. Weston, to the sole management of their affairs, and he being recommended to Mr. John Smeaton, F.R.S., by the president of the Royal Society, employed this gentleman to devise the means, and superintend the erection, of a new building. Mr. S., whose originality of genius, and soundness of judgment, have since been so generally known, was at that time just entering into his profession as a civil engineer, but immediately devoted himself to the consideration of the light-house, and soon determined upon erecting a stone building; and reasoned, that by making the building very heavy, and uniting all the stones firmly together, he should obtain such a weight and strength, as would firmly resist the united action of the wind and water. He determined upon dovetailing the stones together, as being a more secure method than cramping with iron, and not liable to interruption from the work getting wetted, as would almost unavoidably happen in such an exposed situation. On the whole, the building he erected, and which is now standing, may be considered as the most perfect light-house in existence, and gives examples of the best kinds of masonry. We have therefore given drawings of it in the *Plate of Light-house*, which are taken from a superb work in folio, published by Mr. Smeaton in 1791, entitled "Narrative of the Building, and Description of the Construction of the Eddystone Light-house with Stone." It is from the same source the whole of this article has been compiled.

Fig. 1. is a south elevation of the whole house, and *fig. 2.* a section of the same. A represents the landing place; B a natural cave in the east side of the rock; D an iron rod, serving as a rail to hold by in passing up steps cut in the rock, to the foot of the ladder occasionally put out from the entry door at E. At F is a cascade of water, pouring over a low part of the rock, but this is only momentary, for the swell will in an instant cause it to set the other way. In *fig. 2.* a B shews the upright face of the rock, and the line a b the general direction of its grain or slope. In this figure it is seen that, as high as the first 14 courses of stone work, the building is entirely solid. Here the entry F commences, but excepting this cavity, and the staircase X, the solid still continues to the floor of the lowest chamber G, which is the store room, and H the door at which the stores are drawn up and received. I is the upper store room; K the kitchen con-

taining the fire-place L, from which the smoke ascends by a copper funnel m, through the bed room M and lantern N, to the ball on the top of the cupola O. The ascent from room to room is by the perforations through the middle of each floor, a moveable step ladder being used for the attendants; but store may be drawn up from the lower room into any other. P is the railing forming the balcony; its floor is covered with very thick sheet lead, turned down over the cornice Q, which furmounts the column of the building. R is the stone basement of the lantern, and N the glazed part: the cupola O is supported by eight cast-iron standards, between which the copper window frames are fixed: the standards have claws at bottom, which are screwed to flat iron bars resting upon the stone work. By this means the whole lantern is framed together; and to strengthen it, the window frames are cast with diagonal bars, as shewn in *fig. 2.* The whole lantern is held down by eight bolts at its angles, passing down through the balcony floor; one of these is seen at d: S is the door to the balcony. The lantern is lighted by 24 candles arranged in two iron circles, one six feet four inches diameter, containing 16 lights; and the other, three feet four inches diameter, holding eight candles. These circles are suspended by cords going over pulleys, so that they mutually rise and fall parallel, and counterbalance each other. By this arrangement either circle can be drawn down to snuff the candles, which is done every half hour, without losing the whole light. Having thus described the general outline of the building, the minutia of its construction comes next to be described, and the manner of uniting the stones composing it. The section, *fig. 2.* shews the several steps which were cut in the rock to engraft the stone work upon. *Figs. 1, 2, 3, &c.* denote the different courses of stone, each of which makes a level surface with the step it is fitted into. The seventh is the first complete course. *Fig. 3.* is a plan of the rock, shewing the courses 1, 2, and 3, laid in their places, and exhibiting the dovetails which are cut in each step to hold the several stones in their places; and these stones are so formed as to enlock the others with them in a manner which will prevent any stone quitting its position. The dark shaded stones are moor stones, while the lighter sorts are Portland stone. *Fig. 4.* is a plan of the seventh or first complete course, shewing a central stone with four dovetails uniting it to four others, and these tying in the remainder. All the solid courses are laid in this manner to the fourteenth, which, as before mentioned, completes the entire solid. Every course is laid in such a manner upon the one beneath it, that all the joints break each other, as masons term it, that is, immediately above and below the joints of any course the middle of a solid stone is disposed. The several courses are retained upon each other, to prevent them sliding sideways, by means of joggles, which are plugs or cubes of hard black marble, shewn by the dark squares in *fig. 2.* and in the plan, *fig. 4.* to be received one-half through every two adjacent courses. All the courses of the entire solids have a central joggle j, and eight others, g, arranged in a circle round it, as shewn in *fig. 4.* Above the entire solid, the centre stone is omitted to leave the well-hole for the stair-case, X, or rather, it is composed of four stones, united by hook or dovetail joints, to form, when put together, one piece, large enough to have the well-hole through its centre, and the exterior stones are united to it as a central piece in the same manner, as *fig. 4.* In these courses the continuity of the stones being somewhat broken, double the number of joggles, h, and those half the size, are introduced between the courses. It is to be observed, that none of the joggles, except the centre ones,

some immediately over the others, as the figure would infer, but they break joint with each other to give every part of the solid an equal strength. Above the solid, a new system of building was necessarily adopted: the lower courses were composed of Portland stones to fill up the centre, and moor stones, as being more durable, to make the outside. The whole of the upper works are of moor stone; and dovetailing being no longer practicable, the stones are united by iron cramps and joggles, as shewn in *fig. 7*, which is a plan of the upper or bed-room M. Each stone is here seen to have an iron cramp to join it to its neighbour, and has a small marble joggle to unite it with that above it. The vertical joints are rendered impervious to water, by cutting a notch between every two adjacent stones, so that when they come together it forms a hole of a lozenge shape, and a piece of stone being put down into this hole with mortar, makes a perfect joint, at the same time increasing the bond of the stones. This kind of joint is partly seen in *fig. 8*, at *n*, but one-half is hid by the iron cramps *r, r*, extending over every joint. In this figure they are seen inclined, that they may take firmer hold of the stones *s, s*, forming the sides of the apertures T, for the window. The stones of the different floors are dovetailed together, as in *figs. 5* and *7*, and are rather arched on the lower side, as shewn in *fig. 2*. To retain the thrust of these arches, every course from which a floor springs, is bound by an endless chain inlaid in the stone work, as in *fig. 5*, and run in solid with lead. The chain is shewn enlarged in *fig. 6*. *Fig. 7* is a plan of the bed-room M, shewing the disposition of the three cabin beds *k, l, m*, with a window between each. The dark spot *m* is the smoke funnel, and *n* is the place for a clock.—The reader is now tolerably well acquainted with the construction of Mr. Smeaton's light-house; but in such a peculiarly exposed situation, every trifling operation was attended with difficulty, and demanded thought and ingenuity to devise the means of accomplishing it. On this account we shall briefly follow Mr. Smeaton through his narrative, though it relates circumstances which, if recorded in the account of a common building, would appear impertinently minute. The season when Mr. Smeaton first took up the business of the light-house not being favourable for a visit to the rock, he did not attempt it till April 1756, before which time he had designed the general principles of the building. He found upon the rock the ruins of both the former erections, and several of the moor stones of the late building lying in the gut, which was a narrow channel of twelve feet deep between the house rock, and a reef of rocks to the westward, in which channel the boats coming to the house could lie in fair weather. His first visit was employed in observations on the rock, and in experiments of the time requisite to drill and pick holes of a certain dimension, that he might estimate the time necessary to complete the work on the rock. In succeeding voyages he took dimensions of every part to enable him to make an accurate model, to which he could adapt a model of the intended building. The unfavourable days at sea were employed on shore in examining the stone in the country round, a convenient situation for a work-yard, &c. The dimensions of the rock were taken by the following means: He fixed up the circle of a theodolite, with its index, in the centre of the rock, and levelled it with the spirit-level; a light rod was fixed to the index, long enough, when turned round, to reach all parts of the rock; it was provided with a spirit-level to shew when it stood horizontal. It is obvious that this rod, when turned round, would describe a horizontal plane, and the depth of any point of the rock beneath this plane was ascertained by a rod set up vertically upon the point in question, and ap-

plying the horizontal ruler to it. The divisions on the vertical rod shewed the depth; and the division of the horizontal ruler shewed the distance from the centre, and the degrees of the theodolite circle pointed out the direction. By these means the position and altitude of thirty-two principal points were obtained, which were well marked upon the rock, and a line being stretched from one of these points to another, gave the means of determining the position of the iron stanchions, or any thing else which was remarkable. Having thus, in ten voyages, made all the necessary observations on the rock, and determined upon regulations for the management of the work, he returned to London, and, in his way, visited the various stone quarries in Devonshire, and the isles of Portland and Purbeck. He was employed, till the month of July, in making exact models of the building, when he returned to Plymouth, where he found a vessel, the Neptune Bufs, which had been fitted up for exhibiting a temporary light during the period of rebuilding the house. From some misunderstanding between the Board of Trinity and the proprietors, this vessel was not employed in this manner, but was devoted to Mr. Smeaton's use, who immediately began the works upon the rock; mooring the Bufs near the rock to serve as a retreat for the workmen, who were frequently driven off by the waves. In the month of September the three lower steps of the rock were completed, and the upper ones in a state of great forwardness; after which time, bad weather prevented much more being done that year, and in November the Bufs left her moorings to return to Plymouth, in which voyage she was driven to sea, and narrowly escaped shipwreck. Thus concluded the operations of the year 1756. The winter season was passed in preparing stone work on shore, in building boats, and, by Mr. Smeaton, in a long and valuable series of experiments on the different kinds of cements, which could be applied to the building.

In May 1757, the Bufs was carried out and moored, and on the 12th of June the lowest and first stone was laid in its place; from the great uncertainty of the weather every stone was so contrived, that it was of itself in a condition to resist the wash of the sea, even when it was immediately laid, and before it was hardened. For this purpose, each stone had one or two holes drilled through it before it left the work-yard, and this hole being continued a few inches into the rock or the stone beneath, a strong trenail, or oak pin, was driven through it, to pin it fast in its place: as the dovetails did not of course fit perfectly close into each other, but left space for the mortar; notches were cut in the edges of each stone to receive strong oak wedges, which held them firm until the mortar came to its solidity. As a further precaution to defend the mortar, all the outward joints were coated over with plaster of Paris, as a temporary expedient. The work went on rapidly in this manner, and the second course was nearly set in a few days; but a gale sprang up, which obliged them to quit the work, leaving a few stones of the second course, which could not be set, lowered down into their places, and chained strongly to the rock, by lines inserted into the holes made in each of the stones, to lift them by; and one of the most exposed was secured, by laying upon it, when in its dove-tail, a weight of lead of five cwt. in form of a hemisphere. A storm came on, and it was afterwards found, that this weight had been lifted by the waves, so that the stone beneath it had escaped and was lost, as were four others, from which circumstance the force of the sea on the rock may be imagined. New stones were immediately prepared, and the work renewed. In the progress of the work, it constantly happened, after all precautions, that the cement was washed away in particular

places, and it was always repaired the first opportunity with Pozzolana or Dutch terras; which repairs, if they withstood one rough tide, were never found to fail afterwards; but some places were found so difficult, that it became necessary to mix oakum, chopped very small, with the mortar, and this method always succeeded. On the 11th of August the six basement courses were completed, and the first entire course, N° 7, was begun. All the stones for this course were fitted and put together in the work-yard, as shewn in *fig. 4*. They are numbered, so that after being taken to pieces, they could be re-ordered to the same relative position on the building; but to do this accurately, while they were in the work-yard, radial lines were drawn from the centre to the circumference, so as to intersect each stone; and concentric circles were drawn through the middle of each tier of stones. Where any of these lines crossed the joints, a nick was sawn in the edge of the stone, that the mark might be felt as well as seen; and by the coincidence of these lines the stones were set with the greatest accuracy. On the stones arriving at the work, the central stone was first set; the hole to receive the centre joggle was cut through the centre of course six, and the joggle set up therein, as shewn in *fig. 2*, and the centre stone of course seven let down upon it, a mortar bed being made beneath. When the stone was thus fixed, the joints round the joggle were filled in by grouting, which is mortar made very thin and poured in from ladles. The four stones surrounding the centre were now set, and the work proceeded thus to the circumference, every stone being wedged and trenched as soon as set, and the joints grouted. To fix the eight smaller joggles, they were set, wedged, and grouted into their holes in the lower course; but the holes for their reception in the lower side of the upper course, being only cut half through, did not admit of wedging; they were therefore fixed by the mortar only, as much being put on the top of the joggle as would nearly fill the hole, but not quite, and the remainder was introduced through a hole previously drilled through the stone, and forced down by a wooden ramrod.

The mortar used in the building was compounded of equal portions of lime and pozzolana. The lime was burned from the blue Lyas limestone found near Watchet, a small seaport in Somersetshire. It was carried out in tight casks, which were opened at the rock, and a small quantity beat up in a strong bucket with a wooden pestle, and used immediately. The work proceeded in the same manner without any deviation or accident, except now and then losing a few stones by storms, until the end of September, when the ninth course, being completed, the work was given up for the year, and the Buys left her moorings.

During the winter, the buoy of the moorings for the Buys was lost, but was recovered on the 11th of May, 1758. Yet, before any work could be begun, the chains were broken, and the buoy of the anchors having got loose, the moorings were lost; much time being consumed in preparing new ones, it was the 2d of July before the work was renewed; but by the 8th of August, the 14th course, completing the entire solid, was laid, and by the 20th the entry door was covered in, and by the 24th of September, the whole of the solid, up to the store-room floor, was finished. Above this the method of working was totally altered, but not being now so liable to the action of the sea, it became less difficult, and requires less description. In addition to what has been said before, the iron cramps were all filled in their places with lead, and a whole course was done at once, by putting each cramp into a kettle of red-hot lead, till it was equally hot. A small quantity of oil was poured into the holes in the stone, and the hot cramp put in: this oil caused

the lead, when poured in, to occupy every cavity in the stone.

On the 30th of September, the work had arrived at the store-room floor, and here the iron chain, shewn in *fig. 5*, was let into the stone, and filled in with lead in the following manner:—the chain was oiled before putting it in, and the groove divided into four parts by dams of clay. Two kettles were used, which together would hold lead enough to fill the whole groove, which was 11 cwt. In these the lead was made red-hot, and two persons with ladles filled the lead into the same quarter of the groove. As soon as it was at all set, they removed one of the clay dams, and filled the next quarter, pouring the lead on the end of the first quarter, till it re-melted and united with the second. The dam at the opposite end of the first quarter was now removed, and the third filled, and then the 4th. By this means the lead was all round united in one mass.

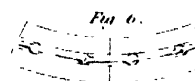
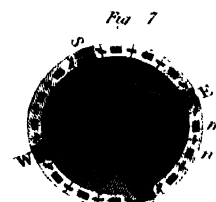
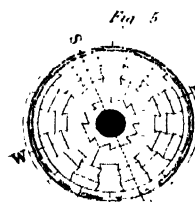
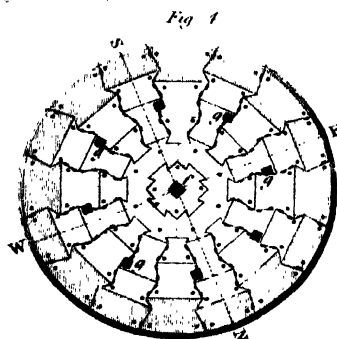
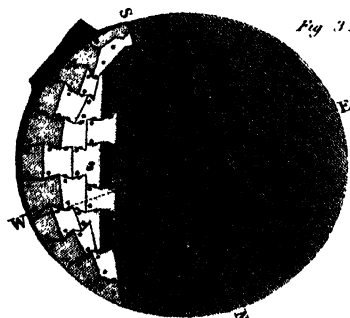
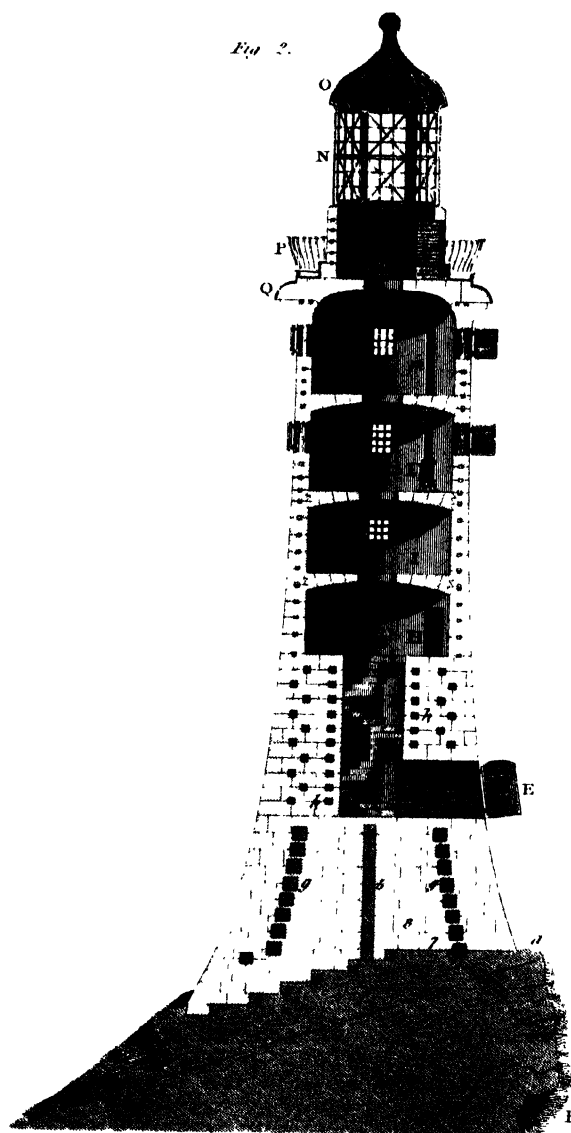
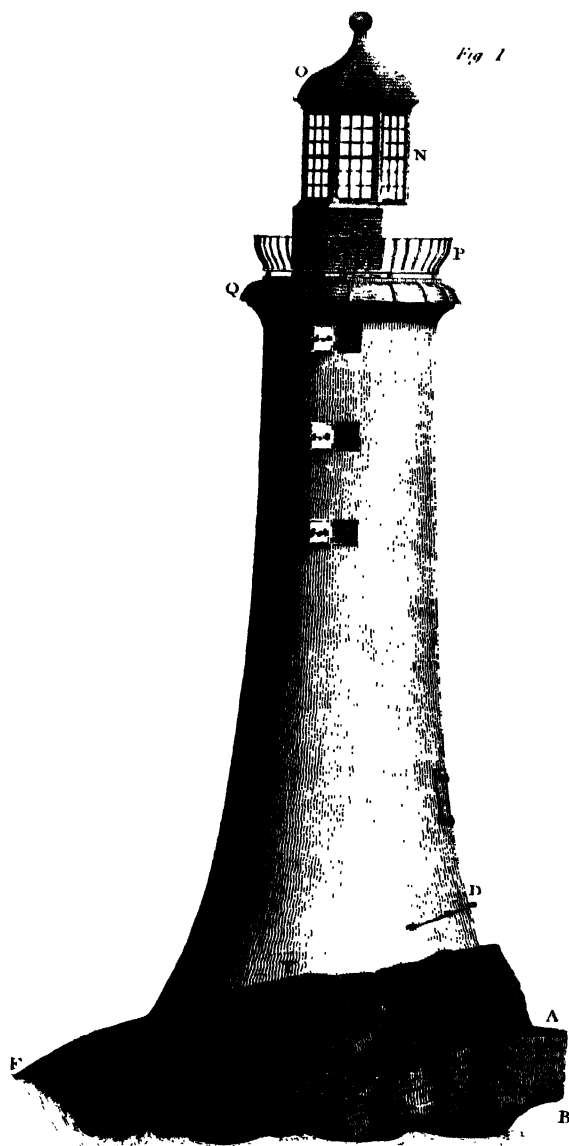
The centering for the floor was next set up, and the floor partly put together, the outward stones being set first, and then the centre ones. When the first room had been thus finished, Mr. Smeaton proposed exhibiting a temporary light during the winter, and, by fixing three floors in the well for the staircase, to form store rooms, and lodging for two men: but this idea was given up, as it did not meet the approbation of the Trinity corporation, and the work was, on the 7th of October, left for the year, the floor being partly finished. The winter was spent in preparing the iron, glass, and copper work for the lantern; and the spring in unsuccessful endeavours to recover the moorings which were again lost, and on the 5th of July the work was begun again. They found one of the stones for the floor, which was lodged in the store room H the year before, had been washed down the well, and thence through the entry into the sea, though it weighed four or five cwt. The stones for the building had hitherto been raised out of the boats, by what are termed *shears*, formed of two poles, united at top, and their feet pitched on the rock close to the building, at a proper distance asunder. A block of pulleys was suspended from the top of the two beams, to take up the stone. The shears were supported by a tackle called a guys, which was attached to the top of the shears, and hooked to the far side of the building, so that the stone, being raised up from the boat by a windlass fixed on the rock at Y, *fig. 1*, the guy was drawn in to swing the stone over the building. When the work got above the entry E, the stones were landed into it, and drawn up the well X by a tackle suspended from a small triangle set over the well; but when the floor was covered in, the hole in the centre being too small to let the stones come up, a smaller pair of shears were made to lie upon the building and rise as it advanced. These were worked by a windlass set up in the store room H, and as they hung over the sides of the building, they drew up the stones clear of the wall. The work proceeded in this manner till the 17th of August, when the last piece of the cornice Q was fixed, which completed the whole column, and the workmen were enabled to lodge in the building. The balcony rails P, and the stone base of the lantern, were soon completed; and by the 26th, the stairs and all the masonry were finished. The iron frame of the lantern was next screwed to either in its place, all the joints being first smeared with thick white lead and oil to prevent them from rusting: it was then raised up on wedges a small height, and lead poured in the joint between it and the stone to make a solid bed for it upon the stone. On the 17th of September, the copper cupola O was set up, by a particular kind of shears made for the purpose, the guys, in different directions, being fastened to booms projected out from

the several windows of the upper room. The next day the ball, which was double gilt, was screwed on ; and by October the 16th, an electrical conductor was fixed, which finished the edifice. A light was then exhibited, which has been continued ever since without any particular occurrence, or any accident produced by the many violent storms which have happened since. Mr. Smeaton has, in the title page of

his narrative, given a representation of the house in a storm, as seen through a telescope from Plymouth, when the waves dash up against the building, till they meet the cornice Q, by which the water is thrown off in all directions in a white column, which envelopes the house like a sheet, and rises to at least double its height, though the top of the ball is 100 feet above low water. See BEACONS.

LIGHT HOUSE.

LIGHT HOUSE on the Eddystone Rock.



0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 Feet

Lignite

LIGNITE. This name is given, by Brongniart, to the species of inflammable fossils, called *braun kohle* (brown coal) by Werner. The following account, from Brongniart's *Traité de Minéralogie*, will supply the omission of the article *Brown coal* in our work.

Lignites vary in colour from deep and shining black to a dull earthy-brown: the texture of most of the varieties indicates their origin and explains their name. The ligneous texture is often observable, though sometimes it has wholly disappeared. Its fracture is compact, often resinous and conchoidal, or shining and even.

The combustible minerals belonging to this species are characterised by their smell and the products of their combustion. The odour which they emit in burning is pungent, often fetid, and has no analogy with that of coal or bitumens. They burn with a pretty clear flame, without bubbling and caking, like coal, and becoming fluid in the manner of the solid bitumens; they leave powdery ashes similar to those of wood, but often more abundant, more ferruginous, and more earthy. The ashes contain a small portion of potash; at least Mr. Majon has found about 3 in 100 in those of the bituminous wood of Castelluovo. These combustibles yield an acid by distillation, which coal does not.

The external characters of the varieties of this species vary too much to allow them to be farther generalised.

1. *Jet Lignite; Jayet. Pech kohle, Wern.*

This substance is hard, solid, compact, and susceptible of a bright polish; it is opaque and of a pure black colour; its fracture is undulated, and sometimes shining like that of pitch. Specific gravity 1.259. It is said to be sometimes lighter than water; but Brongniart thinks this property rather belongs to the following variety.

Is found in strata of little thickness, in marly, slaty, calcareous or gritty beds. It sometimes exhibits the organical texture of wood.

It is found in France; in Provence, at Beleslat in the Pyrenees; in the department of the Aude, near the village des Bains, six leagues to the south of Carcassone (this sometimes contains amber), and near Quihan, in the same department, in the communes of Sainte Colombe, Peyrat, and Bastide; it is situated at the depth of ten or twelve yards, in oblique strata between strata of sandstone; but these strata are neither pure nor continuous. Jet proper to be worked is found in masses, the weight of which is seldom 55 pounds. These mines have been wrought for a long time, and have produced a considerable quantity of jet, which was cut and polished in the same country. It also occurs in Germany, near Wittenberg in Saxony, where it is also cut and polished. Very fine jet has also been found in Spain, in Galicia, and the Asturias. Is likewise said to occur in Iceland, in the western part of the island.

Besides these, professor Jameson has quoted the following localities of pitch-coal or jet lignite: the coal districts of the

Lothians, Fifeshire, Linlithgowshire, island of Skye, and Canaoby and Sanquhar, in Dumfriesshire, in Scotland; Newcastle, Tindal fells, Bolton and Whitehaven, in England; Austria; Hungary, Banuat, Transylvania; Upper Lusatia; Silesia; mount Meißner in Hesse; Würtemberg; Franconia; Bavaria; Salzburg; Italy; Prussia.

Of this combustible ornaments are made, particularly mourning trinkets; it is polished with water on a horizontal wheel of sand-stone. Jet mixed with pyrites is generally rejected.

2. *Friable Lignite; Moor coal; Moor koble, Wern.*

This variety occurs in thick and extensive beds. It is of a lively black, but less shining than that of the preceding variety. Its great friability is particularly characteristic of it. Its surface is always cracked, and its masses divide with the greatest facility into a number of cubic fragments; a character which is not found in jet.

Friable lignite is more abundant and consequently more useful than the two first varieties. It is found in horizontal banks often thick and extensive, but is never seen in such large masses as coal, with which it has been confounded by some; it differs not only by its properties but also by its geognostic situation. It occurs in those masses of sand which often fill up vallies in calcareous mountains, or cover the sides of the hills that skirt them. Is also found, though more rarely, in clayey marle.

Friable lignite is pretty common in the south of France, such as in the department of Vaucluse. Also as considerable mass at Luette, department des Forêts.

Other localities cited by authors are Leitmeritz, Saatz, and Ellenbogen in Bohemia; Thalern near Krems in Austria; Transylvania; Moravia; the island of Bornholm in the Baltic, and the Faroe islands. It occurs more frequently in Bohemia than in any other country. Jam.

It burns without difficulty, but spreads a very disagreeable odour. It can be made use of only in manufactures, or to burn lime. Smiths cannot use it in their forges.

3. *Fibrous Lignite; Bituminous wood; Bituminöses holz, Wern.*

Its colour varies from a clear blackish-brown to clove brown; it has a perfectly woody form and texture; consequently, its longitudinal fracture is fibrous, and its transversal fracture shews the yearly layers of the wood. It is more easily frangible than wood, and takes a degree of polish when cut with a knife.

This lignite often occurs in large masses.

It is found in France; in the vicinity of Paris, near St. Germain, in the isle of Chatou, which appears to be entirely formed of it; and near Vitry on the banks of the Seine, where is a thick bed of trunks of trees well preserved. In the department of Arriège, the clefts of this lignite are filled with calcareous spar. In Liguria, near Castellnuovo, at the mouth of the Magra, it is found in thick and extensive beds. In Hesse, in the mountains of Ahlberg, the stratum is above two yards thick. At Steinberg, near Münden in Hanover, it forms two strata, one of about ten yards, the other of six, separated by a bed of rock from twelve to fourteen inches thick. In England, at Bovey near Exeter, there are seventeen pretty thick strata, situated at a depth of about twenty-two yards under sand and in potters' clay. In Iceland, where it is very abundant, it is called *Surturbrand*; the trunks which form these beds are very distinct, and appear merely to have been compressed.

To these localities we add the following from Jameson: Scotland, in the fletz-trap formation, accompanied with pitch-coal, in the island of Skye; in separate pieces in trapp-breccia in the island of Cannay; in fletz lime-stone, in

the island of Skye, and in the independent coal formation in the county of Mid Lothian; Bohemia, in the Saatz and Leitmeritz circles; Austria; Transylvania; Moravia; Leoban in Stiria; Irfenberg in Bavaria; Upper Palatinate; Landeck in Silesia; Halle; Merseburg; Artern and Eisleben in Thuringia; Kalten-Nordheim near Eisenach; Weh-
rau, Upper Lusatia; Würtemberg; Freienwalde and Königswalde in Brandenburg; Welterwald; Salzburg; Russia.

But this lignite is still more common in small detached masses; it sometimes accompanies the preceding varieties; sometimes it is found alone in small layers, in the midst of banks of clay or sand. It is met with almost every where, and is used as fuel in those places where it is abundant.

This combustible being scarcely decomposed, and hence rather vegetable than mineral, would not deserve to constitute a variety in a system of mineralogy, if it did not pass by imperceptible degrees into the preceding varieties, and into that which follows.

4. *Earthy Lignite; Earth coal; Erd koble, Wern.*

Commonly called earth of Cologne, and sometimes, though improperly, *umber*; but the true umber, which comes from Italy or the east, contains nothing that is combustible, whence it cannot belong to this species.

This substance is black, or blackish-brown mixed with reddish. Its fracture and aspect are earthy; it is fine-grained, easily frangible and even friable; it is rather soft to the feel. Its specific gravity is nearly that of water. It burns, emitting a disagreeable smell.

It not only often contains vegetable remains, but sometimes itself presents the texture of wood, without ever possessing either the colour and lustre, or the hardness of the preceding varieties. It burns sufficiently well to be used as fuel. It gives a gentle and equal heat.

It is found in secondary formation in the neighbourhood of coal mines, and more frequently in alluvial land.

As an authentic example of this variety may be mentioned the earthy lignite from the vicinity of Cologne, known in trade by the name of earth of Cologne. It is dug up at a little distance from that city, near the villages Brühl and Liblar, where it forms very extensive beds of eight or ten yards in thickness, which are situated under elevated ground. It is immediately covered with a bed, more or less thick, of rolled pieces of quartz and jasper, of the size of an egg, and rests on a bed of white clay of an unknown thickness. The bed of lignite is homogeneous, but fossil vegetables are found in it in a good state of preservation; they are, 1, trunks of trees lying one on the other without order; the wood is black or reddish, generally compressed; it readily exfoliates by drying in the open air. Some of these belong to dicotyledonous trees, others are fragments of palms. Among these M. Coquebert-Montbret has found some that are filled with a number of small round pyritic bodies resembling grains of small shot. Similar small, but elongated round grains, resembling a two-celled pod, have been found by Mr. Heim, in the lignite of Kalten-Nordheim. This wood burns very well, and even with a small flame.

2. Woody fruits, of the size of a nut, and which are considered as belonging to a species of *arceuthobium*. The lignite of Cologne contains about twenty *per cent.* of ashes rather alkaline and ferruginous. Its uses are manifold; it is worked in open air with a simple spade, but in order to convey it with greater convenience, it is moistened and moulded in vessels which give it the shape of a truncated cone. It is generally used as fuel in the neighbourhood of Cologne. It burns slowly but readily and without flame, like fungus-tinder, giving a strong heat and leaving very fine ashes. The latter being considered as a very good manure, a part-

of the lignite is burnt on the spot where it is wrought, for the sake of obtaining them.

The earth of Cologne is particularly employed for painting in distemper and even in oil painting. The Dutch use it to adulterate snuff, and if it is not added in too great a quantity it gives the snuff a desirable fineness and softness, and cannot be in the least injurious. Faujas.

This lignite is said to occur also in Hesse, Bohemia, Saxony, Iceland, &c.; but as there has been a confusion between this substance and the variety of ochre called *umber*, we cannot be certain that these indications of localities are referable to earthy lignite.

It may have been observed, from what has been said on the situations peculiar to some varieties of lignite, that this fossil combustible belongs to depositions of the most recent formation, since it is found only in alluvial sand or clay; it seldom or never occurs in stony depositions, except in coarse grained lime-stone and under basalt. In the mountains of Hesse called the Ringe Kuhle, several thick beds of lignite are seen resting on sandstone, and separated by

beds of potters' clay and sand.--(Mohs). On the sea-shore near Calais, fragments of lignite have been found that were penetrated by very transparent globularly aggregated quartz crystals.

The air which circulates where lignite is wrought is generally bad.

From what has been said it appears (our author concludes) that lignite is of a very different formation from that of coal; indeed, Mr. Voigt thinks that there is no transition between these two substances.

The first of Brongniart's varieties of lignite, is by Werner given as a sub-species of his *schwartz kohle*, or black coal.

A variety not mentioned in the above account of lignite, but nearly related to the fibrous lignite No. 3, is the sub-species of Werner's brown-coal, called *common brown-coal*. Its colour is light brownish-black, passing into blackish-brown. It occurs massive. Its fragments are indeterminately angular, more or less sharp-edged. It is found at Bovey, and several other places mentioned under the localities of fibrous lignite or bituminous wood.

Lime

LIME, Burning, a term signifying the process of converting lime-stone, chalk, marble, shells, and other calcareous substances into lime, by means of heat, in kilns properly constructed for the purpose. See **KILN**.

In these cases, the calcination is effected by different sorts of fuel, in different situations, but principally by fossil-coal, peats, or woods; these being laid in layers, alternately with those of the calcareous materials, in the kilns, and the process of burning continued for any length of time, by repeated applications of fuel and calcareous matters at the top, and drawing out the lime from below occasionally as it is burnt.

But mineral coal, or culm, are unquestionably the most convenient and suitable materials for effecting this business, where they can be procured in plenty, and at a sufficiently cheap rate, as they burn the stone, or other calcareous matter more perfectly, and, of course, leave fewer cores in the calcined pieces than when other sorts of fuel are employed for the purpose.

However, Mr. Dodgson has had much success in burning lime by the use of peats; as he states, in the *Farmer's Magazine*, that he is "convinced, from experience, that lime-stone can be burnt to better purpose, and at less expence, with peat than with coal. When coal is used, the lime-stones are apt, from excessive heat, to run into a solid lump, which never happens with peat, as it keeps them in an open state, and admits the air freely. The process of burning, also, goes on more slowly with coal. No lime can be drawn for two or three days; whereas, with peat, it may be drawn within twelve hours after fire is put to the kiln; and in every succeeding day nearly double the quantity of what could be produced by the use of coal. The expence is comparatively small. A man and a boy will dig as many peats in one day as will burn 60 Carlisle bushels of lime, (the Carlisle bushel is equal to three Winchester ones,) and the expence, including drying, will not exceed four, or, at most, five shillings; while the coal necessary for burning the same quantity of lime would have cost twelve shillings at the pit. The wetness of seasons is no argument against the use of peats, as they can be stacked near the kiln, when half dry, at any time of summer; the moisture will be exhaled from

them during winter, and they will be in a fit state for burning in the months of April or May. He lives in the north-eastern district of Cumberland, where the farmers, in general, burn their own lime; and though there is coal in the immediate neighbourhood, he gives a decided preference to peat, for the reasons above-mentioned." And it is well known, that this kind of fuel has been occasionally used in many parts of the kingdom for the same purpose, from a very early period, without any complaint of the want of success.

In the practice here stated, no particular form of kiln was found necessary, nor any particular sort of management in the process of calcination; the proportion of peat depending upon the nature of the lime-stone employed, and other circumstances.

It has been considered by Mr. Marshall, that "the manufacture of lime is an art of which the manager of an estate ought not to be ignorant." And he conceives, that "he ought to have, at least, a sufficient knowledge of its theory, to enable him, when occasion requires, to superintend or direct its practice. For it seldom answers, unless where materials are plentiful and fuel cheap, for every tenant upon an estate to manufacture his own lime. A full-sized kiln accumulates a stronger heat, with a given proportion of fuel, than a small one of the same form," which is without doubt a great saving.

It is supposed, that "the chief or sole intention of burning lime-stone for manure, appears to be that of reducing it in the readiest and cheapest manner to an impalpable powder. For experience sufficiently shews, that quick lime is injurious, rather than beneficial, to vegetation; and that burnt lime-stone does not operate as a manure until it has regained the fixed air, of which the fire deprived it. If it could be reduced by mechanic powers to powder of equal fineness, its effect, as manure, would doubtlessly be the same as that of dead lime (effete). It is in the perfect solution which well-burnt lime-stone has received, by the expulsion of its fixed air in the fire, so as to have completely loosened its texture, and unbound its every atom, that we are to look for its prompt effect and the shortness of its duration, comparatively with unburnt calcareous substances. Hence

LIME

the main point to be attended to is to expel the whole of the air. For, unless this be accomplished, the solution becomes imperfect; the stones, instead of completely dissolving into impalpable atoms, break into granules, or flakes; leaving, perhaps, a firm core in the centre, to encumber, rather than to fertilize, the soil" on which they are applied. "There is, however, an opposite extreme to be avoided, and with greater care. For an unburnt stone may be returned to the kiln, but one which, by too intense a heat, is vitrified, or changed to a state of impure glass, is not only rendered useless, but has incurred an extraordinary waste of fuel. Consequently, stones that are prone to vitrification ought to be broken down into small pieces; otherwise, the fire is required to be so intense, that the surface becomes vitrified, before the air from the centre can be expelled." And "another suggestion, respecting the proper size of the stones to be burnt, may have its use. Where fuel is weak, or dear, the materials require to be broken into smaller fragments, than where a strong fire can be kept up at a small expence; while, under the latter circumstance, and where the stone is not prone to vitrification, much of the labour and expence

of breaking may be saved, by using an extra quantity of fuel, and keeping up a strong fire in the kiln," or place where it is burned; the form or construction of which depends partly on the qualities and value of the materials, and partly on the kinds of fuel that are made use of, and the differences of their prices at the places where they are employed. See KILN.

It is useful that the process of burning lime should go on during January and February, as well as most of the winter, and also in the summer months. Perpetual kilns are wrought in many districts, especially the northern ones, and in Ireland; the lime, when not taken away, being preserved, in sheds erected for the purpose, from the wet. The usual mode of managing with them is, for the farmers to contract for some sort of measure, according to the custom or practice of the particular district; being careful that it is well burnt, and of a proper quality in other respects. The differences in the expence of burning will depend on the abundance or scarcity of fuel, and the convenience of the stone for carriage.

Liverpool

LIVERPOOL, a market town, borough, and sea-port, in the county palatine of Lancaster, England. It is placed on the eastern bank of the river Mersey, which flows into the Irish sea, not far north of Liverpool. The population of this town, according to the parliamentary returns of 1800, amounted to 77,653 persons, who occupied 11,446 houses.

The etymology of the word Liverpool is much involved in obscurity, though many ingenious antiquaries have endeavoured to ascertain it. The most general opinion is, that it owes its origin to a species of bird called the *lever*, great flocks of which are said to have frequented a pool in this neighbourhood, during their wanderings from their native climes. Accordingly a bird has, from time immemorial, been the impression on the corporation seal. The early history of this town is equally as unknown as the derivation of its name. Fortunately, however, the deficiency of records concerning it cannot be felt as a great loss, as there seems little reason to suppose it was of any importance, either commercially or politically, previous to the commencement of the last century; hence it may be called a modern town.

"Yet scarce an hundred annual rounds have run,
Since first the fabric of this power begun;
His noble waves inglorious, Mersey roll'd,
Nor felt his waves by labouring art control'd.
Along his sides a few small cots were spread,
His finny brood their humble tenants fed."

Mount-Pleasant, a poem by Roscoe.

To the active, persevering, and liberal conduct of the author of these lines, Liverpool is materially indebted for its present increase of buildings, commerce, &c. and it would have reflected credit on the free burgesses of the town, had they continued to elect him their member.

In the Conqueror's survey, it is stated, that all the land between the rivers Ribble and Mersey belonged to Roger de Poitiers; but there is no mention either of a town or village. Hence it may be reasonably supposed none existed at this time. A castle, however, is noticed by Camden, as having been built shortly after the conquest, the command of which was bestowed on Vivian de Molyneux, a Frenchman, in whose family it continued till the 30th year of the reign of queen Elizabeth.

Neither history nor tradition determine any thing certain, either concerning its founder or the period of its erection.

The tower, which forms part of a prison in Water-street, is the only building of antiquity which Liverpool can now boast of possessing. The original founder of this tower we are as ignorant of as we are of the founder of the castle. Seacombe, in his Memoirs of the Stanley family, is the first author who mentions it. He tells us, that it was the property of sir Thomas Latham, in the reign of Edward III., whose daughter and heiress married sir John Stanley; but says nothing of its erection. The cross which formerly stood at the corner of Pinfold lane, opposite the Flashes, has been long demolished. This tradition reports to have been placed there in commemoration of St. Patrick, who, it is said, rested in this neighbourhood on his way from England to Ireland.

The first charter in favour of Liverpool, according to Enfield, who published a history of Liverpool, was executed in the reign of Henry I., but the accuracy of this statement is extremely doubtful. It is certain, however, that in the charter granted by king John in 1203, nearly a century afterwards, this town is called a borough by prescription. Henry III. confirmed the privileges of the corporation in the year 1227. From this period, to 1555, we are totally in the dark as to its history or condition; nor is there any thing worth remarking for the 16 years following, when the inhabitants sent a memorial to queen Elizabeth, praying relief from a subsidy which her ministers had imposed upon them. In this petition they style themselves "her majesty's poor decayed town of Liverpool." How the town became so "decayed," it is now difficult to comprehend, as, from the records several years previous, it does not seem to have been any better than a fishing hamlet, containing about 138 householders and cottagers, and possessing 12 barks, navigated by 75 men. Camden, however, who wrote in 1586, considered it in his time as more famous for its beauty and populousness than for its antiquities. To reconcile these opposite statements, it is only necessary to admit, that a very trifling village may arrive at considerable opulence in the short period of 21 years; and who will deny the possibility of such an event at the present day? From Camden's time nothing is recorded of Liverpool deserving of notice till the year 1644; when the town and its castle were possessed by the parliamentary troops, under colonel Moore. It was fortified and secured on the land side by a high mud wall, and a ditch twelve yards wide and three deep. Batteries were erected at different points, and the ends of the streets were defended by artillery. The garrison was numerous, and being well stored with provisions, made a most vigorous defence for the space of a month. At last, however, the king's army, under the orders of prince Rupert, succeeded in taking the town, when the castle surrendered without further resistance. Some traces of this siege can yet be discovered at different points. When the foundation of the present infirmary was sunk, the marks of trenches were distinctly visible, and many articles of modern warfare were found within their scope. A few years ago, as some workmen were removing the earth in a field where Gloucester-street now stands, they laid open the foundation of a battery, and discovered military utensils of different kinds. From the time of the siege till 1680, we have a tolerable account of the progress of the town in extent and population. After this period, however, we are again left in obscurity, and receive no authentic information on that head till the year 1765, when we find a plan of the town made by Mr. John Eyes. About this time, says Enfield, Liverpool contained about 4200 houses, and 25,000 inhabitants. It had, in the interval last-mentioned, been constituted a distinct parish from that of Walton, to which its

church had formerly been only a dependent chapel. This event took place in 1608, when the inhabitants were likewise authorised to build a second church. Thus emancipated from parochial subserviency, Liverpool began to display its energies. In the short space of little more than half a century, this town, aided by a few favourable circumstances, has risen to great commercial importance, and may be considered to be next to the metropolis itself. She first rivalled, and latterly surpassed, Bristol, which had long been considered as the western emporium of trade.

The following table exhibits the progressive increase of the dock duties for several years, and serves to display the vast and rapid increase of the commerce of the town. It shews the number of vessels that have been assessed in each year, with the aggregate sum paid to the dock companies.

<i>Years.</i>	<i>Ships.</i>	<i>£.</i>	<i>s.</i>	<i>d.</i>
1760	1245	2,330	6	7
1765	1930	3,455	8	4
1770	2,73	4,142	17	2
1775	2291	5,384	4	9
1780	2261	3,528	7	9
1785	3429	8,411	5	3
1790	4223	10,037	6	2
1795	3948	19,368	16	4
1800	4746	23,337	13	6
1802	4781	28,192	9	10
1805	4618	33,364	13	1
1807	5791	62,831	5	10
1809	6023	97,580	19	3

The boundaries of Liverpool extend considerably beyond the town in different directions. These are marked out by stones called by the inhabitants meer-stones, and the ground contained within them is denominated the liberties. The extent of the liberties from east to west, is somewhat more than a mile and two furlongs, and from north to south considerably above two miles. This town exhibits, in general, the appearance of opulence and refinement. The streets are well paved, and during winter tolerably furnished with lamps. Of late years it has received many great alterations and improvements, which still continue to proceed notwithstanding the pressure of the times. In the year 1790, it consisted of 8865 houses, but their number now is little short of 13,000.

Liverpool possesses fifteen churches belonging to the establishment, some of which are worthy the particular attention of the stranger. Near the old church, which is dedicated to our Lady and St. Nicholas, there formerly stood an image of the latter, to which the sailors were accustomed to make offerings on going to sea. This church has been lately rebuilt. The tower of St. Peter's, which was erected in 1704, is a well-proportioned octagon, each side of the angles having a candlestick and gilt vase representing a flame. This and St. Nicholas are the parish churches, and have two rectors over them. The church of St. George, built on the site of the ancient castle already mentioned, is a fine edifice of the Doric order, crowned with an attic wall, and adorned with a variety of vases. On each side is a terrace with recesses underneath. The interior is handsomely fitted up, the fronts of the galleries being mahogany. This is the mayor's chapel, where he attends every Sunday, and where pews are appropriated for the gentlemen, including strangers, who choose to accompany him. St. Thomas's church is of the Ionic order, and has a handsome appearance. It was consecrated in 1750. St. Paul's church was erected by the town in 1769. At the west end is a portico with a pediment, having in the centre, on an octagonal base, a dome

with a lanthorn, ball, and cross. The interior is supported by eight Ionic pillars. The altar is plain and neat. The church dedicated to St. Ann, on the road to Everton, is a neat building of brick and stone. It was erected at the joint expence of two private gentlemen. It has a tower decorated with pinnacles. St. John's church is a new building of stone, with a tower. St. Mary's and the other churches have nothing connected with their structures or appearances deserving of particular notice; though all of them are entitled to be called neat. Besides the places of worship belonging to the establishment, there are a great number of dissenting meeting houses, or chapels, for various descriptions of religionists.

The public edifices connected with the trade and commerce of the town are, the exchange Buildings, town-hall and mansion house, custom-house, corn exchange, tobacco warehouse, and other warehouses. Of these the Liverpool exchange is the most spacious in plan, and ornamental in its exterior architecture. It has been erected by a subscription of 80,000*l.* raised by 800 transferable shares. The buildings occupy three sides of a quadrangle, having the town-hall on the south side. The whole surrounds an area of 194 feet by 180. It has been built by John Forster, esq. (architect, engineer, and dock master to the corporation) from designs by James Wyatt, esq. architect; and is appropriated to a public exchange rooms, coffee rooms, and various offices. The town-hall, formerly called the exchange, is a large insulated pile of building, the greater part of which was erected in 1750, from the designs of Wood of Bath. The whole of its interior was burnt in 1795. It was soon repaired, and appropriated to the use of the mayor, for offices belonging to the corporation, sessions rooms, &c.

The infirmary is another excellent building of brick ornamented with stone. This establishment not only extends to all proper objects within Liverpool, but to every person whom sickness or bodily misfortune may lead to apply, provided they are recommended by a subscriber. The seamen's hospital forms a portion of the buildings of this infirmary, being attached to it by a handsome colonnade. The blue-coat hospital is placed in an airy situation adjoining to St. Peter's church-yard. It is a large handsome building of brick ornamented with stone. The number of persons who annually receive the benefits of this charity are about 280. The expence of this institution is defrayed chiefly by benefactions.

The poor-house is a handsome edifice, 90 feet long and 24 broad, built in a plain style, and in a manner very suitable to its use. On the east side of this structure is a handsome stone building, called the "recovery ward," where persons infected with fevers, and coming under the cognizance of physicians and surgeons of the dispensary, are received. A variety of almshouses range out on both sides of the poor-house. In Church-street is the dispensary, which is a very good brick building, with a large circular portico, and having in front a small bas-relief of the good Samaritan. This institution is conducted by a president, two auditors, seven physicians, three surgeons, and one apothecary, who officiates as secretary. Two physicians and a surgeon attend every day at certain hours. About 10,000 persons are said to receive medicine and advice here annually. The Lunatic-asylum is contiguous to the infirmary, but, like most other institutions of the kind, cannot be called a complete charity, as patients are not admitted free of expence. At the entrance into the town, on the road leading from Prescot, stands the school of industry for the indigent blind. The original projector was Mr. John Christie, who was him-

self unfortunately deprived of his sight at the age of 19. In this school pupils are taught various trades, which enable many of them to make a comfortable provision for life. Besides these charitable institutions there are a number of others, under different names, intended for the relief of different descriptions of persons, which the limits of an article like this will not permit us to mention particularly.

Liverpool abounds, as may be supposed from its great trade, with rooms appropriated for public correspondence, and the transacting of business. The Athenaeum, which comprises a news-room, a library, &c. is situated on the south side of Church-street, and is a handsome building of stone. The subscribers to this institution, about 450 in number, are supplied with the London and provincial newspapers, the shipping and trade lists, and various periodical publications. Every subscriber is allowed the privilege of introducing his friend, provided he be a non-resident of the town. There also several more institutions of a similar kind in different parts of the town. Of these, the Lyceum is the first and most worthy of attention. It is situated at the bottom of Bold-street, and is another remarkable instance of the munificence and public spirit of Liverpool. An academy, for the encouragement of the fine arts, has recently been established in this town. The places of public amusement are now little inferior to those in the metropolis. The theatre is a spacious and commodious building, and but little inferior to that of Covent-garden in the extent of its stage. It generally opens at the time the London houses shut; when many of the first performers resort to it. In Bold-street stands the Music-hall, which was opened in 1785. It is a large building, finished with great elegance. The new prison, according to the Howardian plan for solitary confinement, is on a very extensive scale, and has every possible convenience.

Liverpool abounds in docks for the safety and repair of its numerous shipping. The first dock was constructed here in 1710. Its site was the pool, from which the town derived the latter portion of its name. This basin of water is called the old dock, and is principally the receptacle of West India and African ships, being contiguous to the warehouses of the merchants engaged in those branches of commerce. The King's dock is 290 yards in length, and 90 wide. On the east side of this dock stands the tobacco warehouse, where that article is lodged by the custom-house officers till the duties are paid. It was erected by the corporation, and is rented by government at 500*l.* *per annum*. St. George's dock was the third made in Liverpool. It is about 260 yards long, and 100 broad; and is esteemed commodious. The largest, last constructed, and best finished however of the Liverpool docks, is the Queen's dock, which is situated at the bottom of Parliament-street. Salt-house dock, which is the second oldest of the whole, comprises an area of 21,928 square yards; and has a length of quay of 640 yards. Besides these there are five graving docks, and three dry docks, independent of a small one, which belongs to the earl of Bridgewater, for the use of the canal flats. Some of these docks communicate, so that ships can pass from one to the other, and into the graving docks, without being obliged to go into the river. All the wet docks are likewise connected by large tunnels, for the purpose of one dock cleansing or washing another. When large ships loaded arrive at neap tides they are compelled to remain in the river till the flow of the spring tides, as the dock gates have not depth of water sufficient to admit them. This circumstance is certainly a great inconvenience, but it is amply compensated by the capaciousness and excellent arrangement of the docks themselves.

The custom-house is situated at the east end of the old dock. It is built of brick, in rather a neat style. A small flight of steps leads to a piazza, over which is the long room, and behind it are extensive warehouses. At the south end of the town is St. James's walk, from which the spectator has a fine view of the town, the harbour, the river, the sea, and the Welsh mountains. Behind this lies an excellent quarry, the entrance of which is by a subterraneous passage, supported by arches. Bootle-springs, about four miles distant from Liverpool, supply the town with water, which is conveyed by means of pipes.

The principal manufactures are those of china and earthen ware, the several branches of the watch making, and extensive salt, iron, and copperas works. It is computed that about 3000 shipwrights are constantly employed in the different dock-yards of this town. The river, which is here about 1200 yards broad, abounds with salmon, cod, flounders, and turbot. Ships of any burden may come up to this town with perfect safety, even at the lowest tides. The accommodations for sea-bathing have, of late years, received vast improvements, and are not perhaps inferior to any in the kingdom.

Liverpool undoubtedly owes all her opulence and grandeur to the spirit and enterprise of her merchants. She exhibits, to the eye of the statesman and philosopher, a distinguished instance of the rapid progress of commercial greatness. A century ago, a few coaling vessels and petty traders formed the whole of her wealth. For the first fifty years her advance was comparatively slow. After this period, however, the increase of trade which she every year acquires, is truly astonishing. She shares a portion of the

commerce of almost every country in the world. Of late years, Liverpool has considerably decreased, in common with that of all the other towns in the kingdom. What effect the abolition of the slave-trade may ultimately have upon Liverpool, it is not possible to prognosticate. For the present, however, the mercantile houses, formerly engaged in that traffic, must undoubtedly suffer considerable difficulties before they can turn their capital and attention to some object more honourable than the purchase and sale of human beings.

Independent of the advantages Liverpool possesses for foreign commerce, it has communication with all the interior counties by canals. These again, being joined by others at different points, extend themselves to the Severn, to the Humber, and to the Thames; thus connecting the four principal trading ports in England. To the beneficial effects of these canals Liverpool has to attribute much of her present greatness.

The markets of Liverpool are well supplied with every necessary of life, and every article of luxury. About 3000 cattle and sheep are brought into the town weekly. The market days are Wednesdays and Saturdays. Liverpool sends two members to parliament. The number of electors amounts to above one thousand. The corporation consists of a mayor, two bailiffs, and a common-council. The mayor and bailiffs are assisted by a recorder, a town clerk, and other necessary officers. The revenues of the town are very great. Enfield's History, &c. of Liverpool, folio. A General and Descriptive History of Liverpool, by Wallace, 8vo 1797. The Picture of Liverpool, 12mo. 1805. Beauties of England, vol. ix.

Lock

LOCK, a well-known instrument for securing doors and preventing them from being opened, except by means of the key adapted to it. A common lock consists of a strong bolt, which must be fitted in a proper box or case affixed to the door, and inclosing it on all sides, to defend it from violence, that it cannot be withdrawn, except by the application of the key, which should enter the lock by a small key-hole, and be surrounded by numerous wards, that occasion the passage the key passes through, in turning round to move the bolt, to be very crooked and intricate, and thus preventing the introduction of any instrument or false key to withdraw the bolt. The third part of the lock is the tumbler, which is a catch or click holding the bolt from being withdrawn, except the tumbler is first removed by the key, which is done at the same time it shoots the bolt. This common lock cannot be made perfectly secure from being picked or opened without the right key, from the circumstance that the wards, though they may be variously disposed, so as to require a very crooked key, must be always left fixed in the lock, and their figure may be taken by introducing a small false key, covered with wax or other plastic substance, and receiving the impression of the wards, from which information a false or skeleton key may be made, that will enter the lock and withdraw the bolt; or, if it will only raise up the tumbler, the bolt may sometimes be forced back by other means. Another reason of the insufficiency of the common lock is, that the variations capable of being made in the arrangement of the wards are not sufficient to produce the required number of locks without having great numbers exactly alike, and their keys capable of opening each other reciprocally; from which circumstance they become but an imperfect security, as any ill-disposed person

may, by furnishing himself with a great variety of old keys, be enabled to open almost any common lock; particularly if these keys are filed away to skeletons, that is, leaving as little as possible of the solid part of the key, which will then have a greater chance of passing in between the intricate wards.

To produce a lock which would be free from these objections has been the study of many ingenious mechanics, whose various locks have different properties and advantages. We have devoted *Plate XXI. Miscellany*, to the explanation of two capital locks, one by Mr. Thomas Rowntree, which is an improvement upon the common tumbler-lock, and another by Mr. Joseph Bramah, which is on an entirely different principle.

Mr. Rowntree's lock is represented in *figs. 5, 6, 7, and 8*; in these the following parts are those of the common lock: A A is the plate which incloses the whole mechanism, and fastens it to the door; B B, *fig. 6*, is the bolt, which is guided in its motion by sliding under two bridges C, D, screwed to the main plate; E, E, are four pillars which support a plate to cover the works: this plate has the key-hole in it; F, &c. are the circular wards surrounding the centre pin; and *a*, *fig. 6*, is the key which, in turning round, acts in a notch *r* in the bolt, and shoots it forwards or backwards; G is the tumbler: it is a plate situated beneath the bolt and moving on a centre pin at *d*. See also *fig. 8*, which is a separate view of the tumbler; it has a catch *e* projecting upwards from it, which enters the notches *f* or *g*, *fig. 6*, in the bolt, and thus firmly retains the bolt; the former when it is locked, and the latter when it is drawn back. H is a spring which presses the tumbler forwards; the key *a*, in turning round, acts first against the part *c c* of the tumbler, and

raises it so as to remove the catch *r* from the notches *f* or *g*, and then the key enters the notch *r* in the bolt, and moves it. In this, which is the common lock, it will be seen there is no security, except what arises from the intricacy of the wards *F* surrounding the key; for a false key, or any other instrument which is of the same length as *a*, will, if it can pass the wards, raise the tumbler and draw back the bolt. Mr. Rowntree has, by applying an ingenious contrivance to this lock, rendered it so secure, that it will be nearly impossible to pick or open it with any other than the true key. To the tumbler he has added a piece of metal *b*, *figs.* 7 and 8, called its *fin*, fixed to its lower side. When the tumbler is locked in the notches *f*, *g*, of the bolt, the fin applies itself to a cluster of small wheels *I*, *figs.* 5 and 8, all fitted on one centre pin beneath the tumbler: the edges of these wheels stop the fin *b*, and prevent the tumbler being raised; but each wheel has a notch *i*, *fig.* 8, cut in its circumference, and when they are all placed, so that every notch is turned to the side opposite the fin of the tumbler, and forming one notch through the whole cluster of wheels, then the fin is at liberty to enter this notch, allowing the tumbler to rise: but when the tumbler is down, and the plain edges of all or any of the wheels are presented to the fin, the tumbler cannot be raised unless the wheels are first put into the right position above-mentioned: this is done by a number of levers *K*, *figs.* 5 and 7, all centred on one pin at *k*. At the opposite end each has a tooth *m*, entering a notch in the wheel belonging to it, so that when any lever is pressed outwards it turns its wheel round. The levers are pressed towards the key by a spring *n* applied to each, and in this state they rest against a pin *o* fixed in the plate. The wheels are now disarranged completely, every one presenting its plain edge to the fin, but every one requiring a different degree of motion to bring the notch round to the proper position. When the key is introduced and turned round, it first operates upon the curved part *p* *q*, *fig.* 5, of the levers *K*, and raising them, turns all the circles *I* at once into the proper position. The key, in turning farther round, operates on the part *c* *c*, *fig.* 6, of the tumbler, now at liberty to move, and by raising it releases the bolt, and in turning still further round, it seizes the notch *r* of the bolt, as in *fig.* 6, and shoots it. The key is cut into steps of different lengths, as shewn at *v* *v*, in *fig.* R: each step operates on its respective lever *K* in a different degree, and turns its circle *I* the proper quantity. The notch at *c* acts upon the tumbler, and the plain part *t* moves the bolt. In this lock there is no possibility of picking it, for if all the levers except one were raised the proper quantity, that one would detain the tumbler as effectually as the whole number; and a false key, besides having the wards as *R*, must have all the notches *v*, *v*, of the exact depth, neither greater nor less, or it will not open the lock, even if one alone is incorrect. If the key is lost, when a new one is made, the maker takes out the levers *K* and circles *I*, and arranging them in a new order, one upon the other, making the new key to fit the new arrangement, and then the old key will not open the lock; though none of the parts are altered, but only their arrangement. The same may be done if it be suspected that an impression has been fraudulently taken from the key to make a false one by.

The locks invented by Mr. Joseph Bramah display great ingenuity, and demand a particular description, having been in very general use for many years past, and greatly admired. He obtained a patent for his invention in 1784, and established a manufactory of them, in which he employed a number of ingenious tools and engines for the fabrication of the different parts. One of Mr. Bramah's simplest forms of a lock for a drawer, or for a door, is represented in *figs.* 1, 2, 3, 4, *Plate*

XXII. *Miscellany*, in which *A* represents the bolt, fitted to slide on the metal plate *BBC*, by passing through a hole in the side *C*, which is turned up, as shewn in *fig.* 3: the other end of the bolt is guided by passing under proper grooves in the lower side of the circular box *DD*, which is screwed to the plate *B* to confine the bolt down. It contains the whole mechanism of the lock, consisting of an interior cylinder or barrel *EE*, shewn in the section *fig.* 3, with its appendages in perspective in *fig.* 4. This barrel is fitted to turn round within the box *DD*, the upper end *aa* being received into a cavity exactly fitting it, and the middle encompassed by a circular ring of steel plate *bb*, screwed into the box as shewn in *fig.* 3, and one-half shewn at *b*, *fig.* 4. The ring enters a circular groove formed round the barrel, and thus confines it from having any other motion than a rotation on its axis, and this only by the aid of the key *R*, as will be explained. The barrel has a hole through its centre, which is closed at bottom by a circular plate *F*, screwed to it, and supporting the central pin *G*, which occupies the centre of the hole through the barrel: this centre pin guides the key in entering the lock. When the barrel *EE* is turned round by the key, it shoots the bolt *A*, by an ingenious contrivance, explained in *fig.* 2, an aperture being cut through the plate *BBC* to exhibit it. The plate *F*, on the lower end of the barrel *E*, has a pin *f* projecting from it: this pin enters a curved opening, at a small distance from the centre, and therefore describes a circle when the barrel is turned round, cut through the bolt *A*, as is shewn by the dark curve *F* in *fig.* 2. In the position there shewn the bolt is withdrawn, and the pin *f*, resting against the solid part of the groove, prevents the barrel being turned round any farther in the direction from *F* to *f*: but by the application of the key, the barrel may be turned in the other direction from *f* to *F*, in which course it passes round in a circular part of the groove, and therefore produces no motion of the bolt *A*, until the pin *f* strikes the straight part *g* of the groove, and acts against it to throw the bolt forwards: and when the barrel has made a complete circuit, and the pin *f* is again come to the same position it was at first, the bolt is shot out as at *fig.* 1, and the pin is resting in the hollow *b*, which prevents it moving any farther in the same direction. When the barrel is turned back again, the pin *f* acts against the notch *i* and the curved part *k* of the groove, and withdraws the bolt into the position of *fig.* 2: now the pin *f*, either when the bolt is shot out or in, is in a right line with the centre of the barrel *E*, to which it is fixed, and the direction of the bolt's motion. By this means, no force whatever applied to drive back the bolt can have the least tendency to turn the barrel round, and strain the mechanism which prevents its motion, unless the parts are first put into a particular arrangement, by the application of the key. The interior mechanism must be explained by *fig.* 4, in which *l*, *m*, *n*, represent small steel sliders, which are fitted into proper grooves or slits, made in the substance of the barrel *E*. Of these there are six in number, arranged round the barrel, and projecting a little from its exterior surface in the small part. These sliders are received in notches *y*, *z*, in the fixed steel ring *bb*, before described; and thus effectually detain the barrel at six points from being turned round, except it is first unlocked by the key *R* being introduced at the key-hole *H*, and the sliders pressed down by it, so as to bring the notches (of which each slider has one, as at *r* *fig.* 4) all opposite the steel plate *bb*, and then the barrel may be turned round. When the key is absent, the sliders are raised up by a brass ring *v* sliding on the central pin *G*, and lifted up by a spiral spring *w*. The key has six notches cut in the end of it, as shewn at *S*, which is an end view: each notch in the key includes one of the six sliders *l*, *m*, *n*,

and the key, being forced down into the key-hole H, depresses all the sliders at once, until the projecting leaf *t* of the key stops upon the bottom of the recess *x*, cut in the upper edge of the barrel. In this position the sliders are depressed, so that the notch *r* made in each slider comes exactly opposite the steel ring *b b*, and the barrel is at liberty to turn round all the sliders, being by this means removed, or at least relieved, from the steel ring, which, as before mentioned, embraces a groove cut round the barrel, but which cannot turn round therein unless the sliders are also moved by the key, that the notches cut in them coincide with the groove cut round the barrel, and then it can turn freely round. The key, having thus relieved the barrel by being thrust in as far as it can go, obtains a hold of the barrel to turn it round, by the leaf *t* entering the recess *x*, which it exactly fills up, so as to form a continuation of the circular top of the barrel: but as soon as the key is turned round with the barrel a small quantity, its leaf is caught beneath the circular cavity in the top of the box D, and thus the key is prevented from being thrown out by the spiral spring *w*, until it has been turned quite round, and locked or unlocked the bolt: then the leaf of the key coming opposite the enlargement *z*, *fig. 1*, of the key-hole H, the spring throws the key out and raises all the sliders, that they may interlock with the steel plate *b b*, and prevent the barrel from turning, unless the key is again put in, (its leaf being opposite the aperture *z* of the key-hole,) and being thrust forwards as far as it will go, the barrel will turn round very easily; and when it has made a complete circuit, the lock is opened, and the key thrown out of the key-hole by the spring.

The security of this ingenious lock from being picked, or opened by a false key, depends upon a circumstance not yet mentioned, which is, that the notches in the six sliders are so made, that every one requires to be depressed a different quantity to bring them all at once opposite the steel ring, in which position alone the barrel can be moved. For this reason the six notches in the key are all of different depths, correspondent to the positions of the notches in their respective sliders; and unless each notch in the key is of the proper depth, the lock cannot be opened, for any one being too deep, that slider will not be pressed low enough to relieve the barrel, and will hold it fast, though all the others may be correct: on the other hand, any notch not being of sufficient depth, the slider it acts upon will be pressed too far, and in this case the notch in it, having passed by the steel ring, will lock the barrel as effectually as though it was not far enough. Thus this lock admits of an immense number of combinations; 1st, in the number of the sliders; 2dly, the depths of the different notches in the key; and 3dly, the arrangement of these sliders. The combination of these three changes admits such an immense number of varieties of locks, that it never need happen that two locks should be made to open by the same key. Any of Mr. Bramah's locks may be arranged so as to require a new and different key in case the original should be lost or stolen: for this purpose the lock must be opened, and the sliders taken out and changed into different grooves: a new key must now be made, with the grooves of the same depth of the original key, but arranged in a different order, corresponding with the new arrangement of the sliders. The old key will not now open the lock.

To pick a lock of this kind is perhaps impossible; because, though the sliders are exposed to the examination of any person, yet no information can be obtained of the depth of each of the sliders required to be depressed; for, unless they are all together pressed down, the barrel cannot be turned in the least, and without turning it, no guess can be made

by pressing down any one slider of the depth at which the notch in it will be opposite the steel ring. Another great advantage of these locks is, that from the circumstance before explained, of the bolt having no action to turn the barrel, though the barrel has a great power to shoot the bolt, a strong lock may have but a very small key. For instance, the bolt of the lock, in the plate which is drawn its full size, is of great strength, while the key R is so small, that it may always be carried suspended to the watch chain, and then it will not be in danger of being lost or mislaid, as one may happen to lose a key, and give opportunity for ill disposed persons to make a false key from it, unknown to the owner.

A lock invented by Mr. Stansbury, an American gentleman, has great merit. To explain it, we must suppose that a flat circular plate is fitted to turn round upon the centre pin for the key, and that this plate, when turned round, shoots the bolt, which may be done by various means. The locking part consists of four, six, or more small steel pins, which are received in holes made very near each other, through both the circular turning plate, and the fixed plate beneath it. By these pins the circular plate is held fast from turning. The key has the same number of pins, and arranged in the same position and distance as the pins in the plate. The key being introduced, it is pressed forwards against the circular plate, and turned round till the pins in it come over the pins in the circular plate, and the pressure of the hand forces the pins out of the circular plate, the pins in the key occupying the place of them. The plate is now relieved, and the key has hold of the plate to turn it round and open the lock. Each pin is provided with a spring behind the fixed plate to force it forwards. The difficulty of making a false key to this lock is very great; as any error in the number, size, position, or length of the pins, will prevent it from opening the lock. To avoid the danger of impressions being taken, many marks are stamped upon the circular plate, which are exactly the same at the marks of the real pins: thus an impression taken from it would only mislead.

Mr. Stansbury has also made an ingenious improvement upon the common spring door-lock. The handle which opens the spring catch for fastening the door, instead of requiring to be turned round, is made so that it withdraws the spring catch, by pushing the handle on one side of the door and pulling it on the other. This method is extremely convenient; for pressing the handle releases the lock, and continuing the pressure opens the door, and pulling the handle on the other side has the same effect. A person with his hands full may open such a door by only leaning against the handle.

LOCK, or *Weir*, in *Inland Navigation*, the general name for all those works of wood and stone, made to confine and raise the water of a river: the banks also which are made to divert the course of the river, are called by these names in some places. But the term *lock*, or *pound-lock*, is more particularly appropriated to express a contrivance, consisting of two gates, or pairs of gates, called the lock-gates, and a chamber between, in which the water may be made to coincide with the upper or lower canal, according as the upper or lower gates communicating with it are opened; by which means boats are raised or depressed from one level or reach of a canal to another. See *Plate V. Canals*.

LOCK of Water, is the measure equal to the content of the chamber of the locks, by which the consumption of water on a canal is estimated.

LOCK-KEEPER, a person who attends the locks to take

LOCK

care of them, and to assist the boatmen in passing through them.

Lock-paddles are the small sluices that serve to fill and empty the locks.

Lock-fils are the angular pieces of timber, (*b, b*, *Plate V. Canals*, *fig.* 36.) at the bottom of the lock, against which

the gates shut.

Lock-weirs, or *Paddle-weirs*, are the over-falls behind the upper gates, (*x, x*, *Plate V. fig.* 35.) by which the waste-water of the upper pound is let down through the paddle-holes into the chamber of the lock.

Lode

LODE, in *Mining*. This word is derived from the Anglo-Saxon, according to Dr. Pryce, and is used by the Cornish miners to designate any regular vein, whether metallic or not. More commonly, however, it means a metallic vein.

The lodes that are found to contain tin and copper ores, in Cornwall and Devon, have their general direction in a line running nearly east and west; their dip or *underlay* being more commonly to the north; though some which incline to the south have been very productive. Veins which intersect the east and west lodes are, called *cross-lodes*, or *cross-courses*, when their direction is nearly at right angles with the others; and *caunters*, more generally, when their direction is oblique.

The metallic east and west lodes are traversed or disturbed by the cross-courses, and these interruptions are known by the name of *heaves*, which take place to very different degrees of extent, and vary much in the circumstances under which they are found; so that miners do not agree upon any certain rules for determining the distance or direction of the

heave by the accompanying appearances.

Though copper and tin are found but partially in cross-lodes, yet lead has been raised in large quantities from some that have nearly a due north and south course; such as the Beerallstone lead-mines and Wheal Betsy lead-mine in Devon. East and west lodes have sometimes a mixture of lead ores with copper; but this appears to be derived from the intersection of a cross-course, or the effect of a later deposit. Lodes traverse all kinds of rock found in the line of their direction, whether vertically or horizontally. Those worked in Cornwall and Devon are chiefly in killas or grauwacke slate; but they are sometimes in granite, and pass not unfrequently from the former into the latter.

The width of veins varies from an inch or two to fifteen or twenty feet; the latter dimension being rare, as the former is unprofitable to follow, unless in the expectation of an enlargement. The more common width, or, as the miners call it, *the size of lodes*, is from two to four feet; and if such a vein as this be fully impregnated with metal, it is

very profitable to work, and is called a good *course of ore*. The variations of width take place not only in distinct veins, but in one and the same; which, together with the fluctuations in the nature of their contents, render their produce so uncertain. A large and productive lode often dwindles to a mere *branch*, requiring an experienced eye to distinguish it from the rock through which it passes; and this again expands to a considerable size, filled with deposits of various kinds. The width of lodes seems often to have a relation to the nature of the rock in which they are found; and changes in the latter appear generally to produce changes in the former. Thus, a vein that is large and productive in soft blue killas, will, by passing into harder, become less in size, and barren as to metallic contents. Another lode may be rich in hard ground, but poor and unproductive in that which is of a softer kind: but this is not so frequent as the former case. The deposits of metal are as irregular in the lodes as the widths of them; and so much so, as to render the profits of mining proverbially uncertain. Ore is generally found to occupy certain parts of the veins only, differing constantly in extent, whether the length or depth on the course of the vein be considered, or the portion of its width which is filled up by it. No lode has been found regularly impregnated with metal to any great extent; and therefore, when ore is found, it is in what the miners aptly call *bunches* or *shoots*. The unproductive parts of veins, even in the most profitable mines, generally far exceed in extent the productive parts; but that mine is considered to be rich, which has either frequent or extensive shoots of ore: the great art of the miner, therefore, consists in tracing and working the valuable accumulations of the metals with as little waste of labour and expence on the poorer ground as possible.

Although the bunches of ore have no regular form in their vertical or horizontal extent, yet the tendency to a certain direction or dip in the lode may be observed in each bunch or shoot of ore. These shoots are frequently parallel in the same vein; and where the dip or underlay of the lode is to the north, the shoots of ore may frequently be observed to dip west in the lode. In veins underlaying south, the bunches of ore frequently have their dip to the east: but this is not to be taken as a general rule, as many mines afford exceptions to it; the underlay of the lode and the dip of the bunches of ore being reversed.

These tendencies or inclinations of the deposits of metal in the veins, connected with the situations, dips, and bearings of the veins themselves, seem to offer grounds for argument on the disputed question of the mode in which the metals were deposited; but they have not much, we believe, attracted the notice of mineralogists.

Lodes continue to indefinite lengths, and to unknown depths. It is very difficult to determine whether the end of any regular vein has been found or not; as there are many instances of their having become so small as to be scarcely visible, and yet afterwards, on pursuing them, to have resumed their usual size. When a lode has continued small, either in length or depth, to any considerable extent, it is moreover usually abandoned as unpromising; and thus complete evidence as to this question is not obtained.

Lodes are perfect in the surface of the mountains, as well as in their greater depths; and may be traced uniformly by removing the soil with which the rock is covered. This is done constantly by the miner when he is about to undertake operations upon a newly discovered vein. This process is called *cofteening*, or *shoding*. The width of a lode at the surface is no certain indication of its size in depth: as, when large at the surface, they are sometimes found to become

small as they are pursued downwards; and, on the other hand, veins of moderate width *at grafts* have been found, at 40 or 50 fathoms deep, of great size.

The dip or inclination of lodes is seldom uniform. The common *underlay* is from one to four feet in a fathom of depth; but instances occur of a much greater inclination. The lodes that incline much from the perpendicular are not esteemed so promising as those which have a direction more downright; and it is a favourable symptom when a lode, from an oblique direction, is found to turn downwards. On the contrary, where bunches of ore *fail*, or become poor, in sinking on them, it may often be observed that the vein *goes away flat*, as miners express it. Thus it will be understood, that not only are the dips different in separate lodes, but that the same vein frequently varies in this respect. Lodes have been observed to change their underlay, that is, from dipping to the north, to become perpendicular, and even turn to the south. This is not, however, a matter of frequent occurrence.

The underlay of lodes must be ascertained, when it is intended to sink perpendicular shafts to meet them at certain required depths; and from this is determined the distance to be set out north or south from the back of the vein, for commencing such shafts.

Shafts are often sunk *upon* the lodes, and of course these are not perpendicular, but have the same inclination as the veins.

Levels driven from the shafts, are carried on in the substance of the lode, follow its direction, and are the principal means by which discoveries of ore are made and pursued.

The principal methods by which lodes are discovered are the two following: 1. By removing the soil covering the surface of the rock, by which the back of the vein is laid bare, and exposed to view. This may happen accidentally, in the formation of roads, ditches, and so on; or, as is more usual, it may be done for the express purpose of discovery, in consequence of indications of veins being near at hand, such as detached fragments being found, or springs of water impregnated with metal being observed. This process is conducted by sinking trenches, or pits, deep enough to reach the surface of the rock, called by miners the *shelf*; which trenches are called *shoding pits*, or *cofteening pits*. The detached fragments, washed from the backs of lodes, are usually called *shodes*, or *shode-stones*.

The second mode of discovering veins is by levels, or horizontal cuts, driven under ground, which in their progress through the rock, or, as the miners say, across the country, intersect and expose lodes before unknown. Such levels must have a direction across the usual course of the lodes, and are either conducted for the express purpose of finding new veins, or for some other object; and then may occasionally be the means of valuable results of this sort.

Many rich mines have been opened, in consequence of a discovery made by carrying on an adit, or by driving a cross level from a shaft, or from one lode to another known to be parallel to it. The practice of driving adits for the purpose of discovery is more frequent than it used to be. The Tavistock canal has a long tunnel driving through a hill, defined principally for this purpose, and which has already been attended with very great success.

Lodes seldom contain ore near the surface of the ground: it is, therefore, an essential quality in a miner's judgment to decide on the indications presented by them, and to determine the amount of risk which their appearances will warrant on a further trial.

There are niceties in this business which cannot be de-

scribed, but must be seen and studied to be understood, and with which skilful miners are conversant; but the most experienced is liable to have his predictions falsified by the fluctuating nature of these hidden receptacles of various matter.

The indications most depended on, in forming a judgment of the value of a lode, are derived from considering the following circumstances:

1. The nature of the substances contained in the vein.
2. The kind of rock in which it is found.
3. The width and regularity of the vein, considering, at the same time, its direction and dip.
4. The structure of the vein, such as the being open and pervious to water, or, on the contrary, hard and close.

These symptoms may be, on the whole, considered as pertaining to veins containing all kinds of metals, though varying in some in a certain degree: thus a hard close lode may be favourable for tin, though not so for copper or lead.

When a vein is found exhibiting all or most of the appearances which experience has determined to belong to those which are productive, it is called a *kindly lode*, and is generally pursued with vigour, and at an expence proportioned to the prevalence and continuance of the favourable symptoms.

We shall endeavour to consider the principal indications, according to the order above stated, and point out the leading facts to be observed in this important branch of a miner's business.

I. *Of the nature of the substances contained in the vein.*

These substances vary according to the depth to which the lode is opened; those near the surface being generally different from the contents of the vein deeper under ground.

The first thing for which a miner looks is what in Cornwall is called *gossan*. This substance does not appear to have been very accurately described, but is apparently a decomposed mineral of an iron-ochre colour, varying from yellow to brown-red and chocolate-brown. It is of a spongy, cellular texture, of little specific gravity, and is generally soft and friable. It is probably the result of the decomposition of pyrites or mundic, together with quartz, and contains a considerable portion of iron, and not unfrequently a mixture of tin and copper ores. When these latter are present in the combination, it is a most favourable symptom; but even without them, gossan on the back of a lode warrants a trial to a certain extent. It can by no means be asserted, that the most promising gossans have always been followed by ore, on a further pursuit; but perhaps there is hardly an instance of a lode rich in ore, which has not a bunch of *kindly gossan* somewhere on the back.

The next substance, proceeding in depth, upon which reliance may be placed, is *mundic*, including in this name pyrites of all kinds, whether arsenical or sulphuretted, containing iron or copper. Mundic is found at all depths and in all situations in veins: it frequently surrounds bunches of copper ore, and is therefore a favourable symptom, as they are approached; and indicates their decline, when passed through on the other side. It should, however, be recollected, that mundic is very generally found, and therefore it must not be depended on by itself.

The earthy substances, which are esteemed favourable to the existence of valuable metallic ores, are principally quartz, going under the general name of spar; a kind of clay called *flookan*; and, what is not very abundant, *fluor*, distinguished by the appellation of *candied spar*.

The first and the chief ingredient in veins, quartz, is kindly, when it is in a loose friable form, often crystallized,

and cementing detached fragments of killas and the other substances before enumerated. It is unpromising when in a close amorphous form, and is then termed a *sharp hungry spar*.

The *flookan*, or clay, generally forms a branch or vein on one of the walls of the lode, and seems to be the division between that and the rock containing it.

The decomposition of the adjoining strata seems to have been the origin of this substance, which is called by some foreign writers the *saalbande*.

Besides fluor, on which miners are not well agreed as to its promising aspect, and which is not often found in quantity, are some other minerals, likewise of not very frequent occurrence, but esteemed favourable; such as *prian*, a kind of decomposed quartz, and *peach* or chlorite.

Hitherto we have said nothing of the judgment formed by ores found in a lode; it depends upon the following circumstances:

1. The situation, whether shallow or deep.
2. The mode of deposit, whether slightly sprinkled through the lode, or forming fluots or bunches of large or small extent.
3. The quality of the ore.

Under the first head, most miners agree that, as to copper lodes, rich bunches of ore found near the surface are not to be depended on as shewing that a mine will be very productive; it having often been found that such deposits have been followed by poverty at a greater depth. Tin and lead are found nearer the surface than copper. When a lode is spotted with small quantities of ore, and the other substances are kindly, such as the gossan and spar, the appearance is promising; but when the lode is hard, and in other respects unkindly, then small strings of ore are not to be reckoned on as particularly favourable. After a certain depth, a regular branch, or, as it is called, a *leader* of ore of any width, occupying part of a good-sized vein, and increasing or even fluctuating in size as it is pursued, is on the whole the best symptom, particularly if connected with favourable accompanying substances.

Under the head of quality of the ore as an indication of future prosperity to a mine, it must be remarked that nothing requires to be received with greater caution than promises of success supposed to be derived from the richness of individual specimens. We are speaking now more particularly of copper lodes. Few, we believe, of the most profitable mines produce much ore of the richer varieties, which indeed is seldom found to occupy veins of considerable width: on the contrary, most of the best mines are those which yield ore in large quantities, but poorer in metallic content. This observation has been likewise made on the silver mines of South America, according to the account of Humboldt. Copper ores are found in a greater variety of species near the surface than they are in depth; and therefore the miner's experience only will serve to discriminate perfectly on this point: but we wish to put all who are concerned in mining on their guard against a fallacious hope, too frequently excited by the assay of a stone of ore, which in reality often predicts the very reverse of what it is stated to do by the artful or ignorant.

II. The second indication to be attended to, in estimating the prospect of success on a particular vein, has been stated to be *The kind of rock in which it is found.*

It is unnecessary here to go into a voluminous account of rocks, because the great mines of England, as well as of the world, being found in such mountains as are conjectured to be of very early formation, do not admit the varieties in this respect, which some, who are acquainted only with

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other districts, where probably a later formation has exhibited different phenomena, might conjecture.

Lead-mines, indeed, exist in many parts of England, in various rock, and under various circumstances; but no general rules of mining can be formed from deposits of a metal, which appears to have taken its place at a period comparatively late. Such rules can only be applicable to separate districts, where the circumstances attending the deposits are similar.

There are two general classes of rock which claim the distinction of metalliferous above all others. These are the *killas* of the Cornish miner, or grauwacke or transition slate of Werner; and granitic rocks, including porphyry, gneiss, and other varieties, known in Cornwall by the general name of *greowan*.

Of these the great majority of mines are in *killas*, or grauwacke, not only in Cornwall and Devon, but in Scotland, in the Hartz, in the Saxon Erzgebirge, on the Rhine, in Bohemia, Silesia, Moravia, Salzburg, and other districts important for their mineral products.

Granitic rocks are not so metalliferous as the *killas*, but productive veins are found in them; and, as Dr. Berger has well observed in his account of Devon and Cornwall, in the first volume of the Transactions of the Geological Society, even the *killas* is not a depôt of metallic veins to any extent, but near its junction with the granite: and this observation had been made, as he says, by baron Born and Ferber on the mines of the continent.

This fact of most mines being in one prevailing rock, would seem to simplify the exercise of judgment in a miner speculating on the effect of the rock upon the contents of a lode. But though *killas* is so universal, it is far from being all alike; on the contrary, it consists of many varieties. These varieties do not alternate according to certain rules, like the beds of secondary rocks; but exhibit changes in position and extent, more or less frequent, and most uncertain and capricious.

The varieties of *killas*, which are esteemed the most kindly for copper, are the blue and the white, more especially if of a tender, slaty texture. Tin often is found in abundance in harder *killas*, more irregular in its structure, and of a darker colour, indicating the presence of iron. Practice alone can enable men to judge of the shades of difference in these respects, which long experience has pointed out as essential to be attended to: and even then, allowance must be made for exceptions which frequently occur; rules which seem to hold good, when applied to one mine, being often inapplicable to another.

III. The third thing to be considered is *The width and regularity of the vein, and its direction and dip.*

These are important circumstances. If the lode be small, it cannot be expected that abundant deposits of metal can be found; and if it has not the characters belonging to a regular fissure, it is probable that the miner will soon be disappointed, by finding it dwindle to a trifling branch, or split into several insignificant ramifications.

Every large and productive lode is accompanied by other veins running parallel to it, or nearly so, which often fall into the main lode, and generally enrich it by their junction.

These must be carefully attended to, and sought after, as the changes that they produce are often most important, and the quantity of ore which they yield is frequently very great. It has indeed been asserted, that there is hardly a mine working on a single vein only, which has been profitable to any great degree.

The direction of the lode should be carefully ascertained;

because certain ores are only found in veins which have their course in common with others having similar deposits in the district.

Thus the writer of the present article has observed that copper and tin, in Cornwall, must only be expected in lodes running east and west; while lead is raised from such as have a direction at right angles to them, or from north to south.

The more usual dip or underlay, in copper mines particularly, is to the north; but some lodes that underlay to the south have been very productive. In either case, it is no favourable symptom to find the inclination from the perpendicular to be great; and it may be said to be so, if it exceed four feet in the fathom.

When a lode often splits or divides into two or more branches, it is subject to fluctuation in its produce; and these occurrences are important to be noticed with attention, as they afford prognostics as to the future success of working.

IV. The fourth and last head, under which we have arranged the appearances of productive lodes, is that relating to *The structure of the vein, whether open or porous, and thus pervious to water; or, on the other hand, dense and close, and consequently dry.*

All miners agree in this, that water being found to be abundant in a lode is an omen of a very favourable nature; and it is often confidently asserted, that no large returns of ore have been made from dry veins. As far as the experience of the writer of this article goes, it serves to confirm the observation.

Water, indeed, may be found passing freely through cross-courses, and other veins, from which metallic deposits are absent; but then such veins will be found to have all the characters which are adduced as proofs of a later formation, and are therefore easily distinguished from metallic veins.

Large lodes act as natural underdrains, and are channels through which water percolates; so that the rock lying on either side may often be sunk upon with but little interruption from water until the vein is cut into, and then abundant streams flow out, and would put an end to further labour, if it were not for the aid of proper engines to get rid of it.

The quantity of water will of course be, in some degree, proportioned to the extent of the wide and porous parts of the lode; and, as it is from these parts only that much ore can be expected, the water forms in the first instance a pretty good prognostic.

If, in driving upon the course of a small, close, and unproductive lode, a stream of water be suddenly met with, it indicates the approach to an enlargement in the vein, and is a most favourable symptom; and it is, in point of fact, almost always observed before a good course of ore is seen.

The mines of Devon and Cornwall abound with water in a much greater degree than perhaps any others; and as evidence of this, we may adduce the number of vast steam-engines and overhot water-wheels employed for the sole purpose of draining them. We believe, likewise, that when the quantities of ores raised in this district be compared with those of any other which yield them from *true veins*, they will be found abundant in the same proportion.

Under the head of the internal structure of lodes may be noticed the cavities, called by the Germans *druses*, and by the Cornish miners *voogs*: these are observed most frequently in large veins, and in such, of course, assist in the passage of water, and may be classed in the same place as a favourable indication. In these *voogs* are found all the varieties

of crystals; and thus the presence of these in a lode is likewise considered promising, more particularly where observations are made on a vein at no great depth: for as the mine becomes deeper the lode often becomes more compact, and the miner calculates upon finding *solid courses of ore*.

In connection with this part of the subject, the *walls* which enclose the vein are not to be disregarded, when the lode itself is considered, as they should be found to be well determined, smooth, and regular. The rock of which they are formed should be of the hard schist called by miners *capel*; and if penetrated with traces of ore, it may be considered as a symptom of large deposits. On each side of the walls, which usually differ somewhat from the adjoining rock, as if altered by the presence of the vein, the

strata may generally be observed to be twisted or bent downwards, in a slight degree towards the lode, which is in general considered to be more the case near large veins than near those which are smaller.

Having now detailed the principal characteristics of lodes, as important to the practical miner, described the modes of discovering them, and the symptoms by which a judgment is formed of their contents, as far as relates to working them for the metals; we leave the consideration of them, in a geological point of view, for the article *VEIN*. The operations of working upon them will be described under the head of *MINING*, and under that of *ORE*.

LODE, in *Rural Economy*, a provincial term applied to signify ford, in some districts.

Logwood

LOGWOOD, in *Botany*, the wood of a tree; for the botanical characters of which, see HÆMATOXYLUM. The wood of this tree is brought in logs of about three feet in length, to Europe, where it is used for dyeing purples, and for the finest blacks; and therefore it is a very valuable commodity.

The use of logwood in dyeing was established in this country by 13 & 14 Car. II. cap. 11. before which time it was prohibited as a pernicious material. A considerable part of the soluble portion of the wood is taken up both by water and alcohol, but much more by the latter, and these menstrua become tinged by it of a deep purple-red or brown. If acids be added to the watery decoction, it is turned yellow, but alkalies give a very deep purple colour, without yielding any precipitate. Alum, added to the decoction of logwood, causes a violet precipitate or lake, and the supernatant liquor also remains violet, and gives a fresh portion of lake on the effusion of an alkali. The salts of iron give an inky black with all the solutions of logwood, under the same circumstances as with galls, whence the presence of gallic acid in logwood is evinced. The solutions of tin form a very fine violet-coloured lake with the decoction of logwood, and wholly precipitate the colouring matter, so that the supernatant liquor is quite clear and colourless. In dyeing, logwood gives its own natural purple, with shades or variations according to the mordant used, or it heightens and improves the common black with iron and galls. In this latter way it gives a peculiar gloss and lustre, on which account it is a very valuable dyeing material.

Logwood is used in miniature painting to make a purple wash; which may be varied to a more red or blue colour by the addition or omission of Brazil wood. The wash may be prepared by boiling an ounce of ground logwood in a pint of water, till one-half of the fluid be wasted; strain it then through flannel, while of a boiling heat; and add to it, when strained, about ten grains of pearl-ashes. To make it more red, add half an ounce of Brazil wood, or in proportion as the colour wanted may require; using in this case the pearl-ashes very sparingly. This wood has a sweetish subastringent taste, but a remarkable smell. It gives a pur-

plish-red tincture to watery and spirituous infusions, and tinges the stools, and sometimes the urine, of the same colour; but it does not appear to colour the bones of animals.

Besides its use among dyers, it is employed medicinally as an astringent and corroborant. In diarrhœas it has been found peculiarly efficacious; also in the latter stages of dysentery, when the obstructing causes are removed, it serves to obviate that extreme laxity of the intestines usually superinduced by repeated dejections. Extractum ligni campechensis is ordered in the pharmacopœias, and may be given in the dose of one scruple or two, repeated according to the urgency of the symptoms. The extract is obtained by inspissating the decoctions. To promote the extraction, the wood should be reduced into a fine powder, which is to be boiled in the water, in the proportion of a pound to a gallon, till half the liquor is wasted. Some digest the powdered wood in as much spirit as will cover it to the height of about four inches, and afterwards boil it in water; the matters taken up by the watery and spirituous menstrua may be united into one extract, by inspissating the watery decoction to the consistence of honey, and then gradually stirring in the spirituous tincture.

LOGWOOD *Country*, in *Geography*, a district of America, that lies N.W. of the Mosquito shore, at the head of the bay of Honduras, and extends from Vera Paz to Yucatan, from 15 to 18° N. lat. The whole coast is overspread with islets, keys, and shoals, and the navigation is intricate.

LOGWOOD *Lagoon*, a bay or gulf on the N.E. coast of Yucatan. N. lat. 20 57'. W. long. 88 20'.

LOGWOOD *Mill*, in the *Manufactures*, is a machine for reducing logwood, or other dyeing woods, to small chips or raspings, that the colouring matter may be more readily extracted from them by the dyer. These machines are of two kinds: one, by means of knives fixed to a large wheel, chips the wood across the grain into small fragments, which are afterwards reduced to a fine powder, by grinding them beneath a pair of rolling stones: this is called a chipping engine. The other kind operates by steel bars, with a great number of notches in the edge, which rasps and cuts the end of the wood into powder: this is called the rasping engine. Both machines

require an immense power to actuate them, and are generally worked by water-wheels or by steam-engines. A plan and elevation of a rasping engine is given in *Plate XXXI. Mechanics*, *figs. 1 and 2*, where *A* is an iron cog-wheel, turned round by the large cog-wheel of a water-mill or steam-engine; its axis has an iron cylinder *B* fixed upon it, and this has a number of steel bars or knives *a* fixed in its circumference. The pieces of wood to be rasped are placed in a strong wooden trough, *DD*, in which an iron bar, *E*, slides, and forces the wood down to the cylinder, being moved by two racks, *F, F*, turned by pinions on an axis, *G*. At one end of this is a handle, *g*, and at the other a wheel, *h*, which is turned by a pinion, *k*, at the extremity of a long spindle, *HI*, which is turned by a wheel, *K*, whose teeth are engaged by threads of a worm or endless screw, *l*, cut on the end of the main axis. By this means the pinions are constantly turning round with a very slow motion, and advance the wood towards the cylinder, which is at the same time in motion, and its rasps cut the wood into powder. A section of the rasp cylinder is shewn in *fig. 3*, where the same letters are used. In this *m* is the groove in which tenants at the ends of the bar, *E*, slide. This bar has many large spikes in it, which fasten into the wood. At *n* is a strong iron plate at the end of the trough, to defend it from wearing away by the great pressure of the wood down upon it. The wood is kept down in the trough by the cross-bar, *L*, *fig. 2*, fixed down over them. The iron cylinder, *B*, is cast with 24 grooves in it lengthways, and in these are laid as many steel bars, *Y, Z*, *fig. 3*, the section of which is *X*. The angle, *r*, being ground to a sharp edge, and the side, *r s*, cut with teeth, as seen at *Z*, so that the edge is serrated, as shewn by *Y*, the knives are held in their grooves by a strong hoop, *n*, *fig. 2*, driven on the ends of the cylinder over the knives, and they are wedged in fast by small iron wedges. When the wood in the engine is all rasped, and it needs a fresh supply, the pinion, *k*, is disengaged from the wheel *h*, and then the winch, *g*, being turned by a man, the racks are withdrawn. To disengage the pinion, *k*, its bearing is fixed in a beam, *O*, which swings on a hinge at the upper end, and the lower end has a rod, *p*, jointed to it, which is engaged by a catch, *r*, when the handle, *t*, at the extremity of the rod, is moved away from the cylinder, so as to engage the pinion, *k*, with its wheel, *h*. But on moving the end of the rod towards the cylinder, it is relieved from the catch, and the pinion is disengaged from the wheel; and

to prevent the bar, *E*, going so far as to endanger its teeth meeting the rasps, a pin is fixed into a particular part of one of the racks, *f*, which takes hold of the rod, *p*, when it has got as far as intended, and removes the rod from the catch, *r*, and then the racks do not advance any farther to the rasps. The wheel at *RS*, joining in the axes *H* and *I*, is called a friction box: it consists of an iron box, *R*, fixed on the end of the axis, *I*; its cavity receives a conical plug, *S*, fitted upon the end of the other axis, *H*, and pressed into the box by a lever, *T*, loaded with a weight. By this means, if the wood does not rasp away so fast as the motion of the racks would advance it, the cone, *S*, slips round in the box, *R*, and allows for the difference of the movements, which would otherwise break the machine. The cylinders of rasping engines generally turn round from 15 to 20 times per minute, and will reduce a great quantity of wood to a powder in a short time. *Figs. 4 and 5* are two elevations of a *chipping engine*: here *A* is part of a strong iron axis, turned with a considerable velocity by water or steam: upon the end is a small circular flanch, *B*, to which is bolted a circular iron-plate, *D*, in which four knives are fixed, so that their edges project a very small quantity before the surface of the wheel in the manner of a plane iron. *E* is an iron frame containing the bearing for the pivot of the wheel; it has a small trough, *F*, cast all in one piece with it. All this iron work is screwed down to the wood framing, *G G*. The wood, *H*, is in this machine presented to the knives in the wheel by a man who holds it in the trough, and advances it as the knives cut away the end. These chips are cut across the grain but obliquely, as is evident from *fig. 4*: they are afterwards ground to a fine powder by a rolling stone, or runner upon edge. A large and heavy fly-wheel is usually fixed on the axis, *A*, of the chipping wheel to regulate its movement. A method of reducing logwood has been lately introduced by sawing it with a circular saw (see *SAW*), which cuts off a flake from the end of a piece of wood *x*, so that the jar of the saw shatters the flake all into powder. By this means, at every cut the saw cuts away as much wood as its thickness in saw dust and the flake, which is as much more, is reduced at the same time, so that all the wood is reduced, though only one-half is cut, whereas, in the rasping engine, every particle must be cut by the machine. This improvement merits the attention of the woollen manufacturers, whose numerous logwood mills would be much improved by the adoption of this method.

London

LONDON, the metropolis of the British empire, the most wealthy, most extensive, and probably the most populous and powerful city in the world, is seated in a fertile and salubrious plain or valley, on the banks of the river Thames, which divides the town into two irregular parts, and passes through it, from the west to the east, in its progress to the sea. Many cities and towns of antiquity have been famous in the annals of nations: Nineveh was noted for its towers and walls of vast circumference, height, and breadth; Babylon, for the hanging gardens, and other objects of human labour; Persepolis, for its natural fortifications; Palmyra and Balbeck, for sumptuous buildings; and Athens and Rome, for the civilization, refinement, and high accomplishment of their inhabitants. But London may be denominated the modern wonder of the world. The prodigious increase of houses, inhabitants, trade, commerce, and

wealth, with the refinement and luxury which now prevail, render it superior to all the cities of modern Europe; and must excite the astonishment of such foreigners and Englishmen as have studied the local and comparative histories of places of note. It may be regarded as the focus of the British empire; for within its jurisdiction are concentrated the royal, legislative, juridical, civil, commercial, scientific, and literary concerns of Great Britain. Many writers have been employed, at different periods, to narrate the annals of this great town; and several volumes in folio, quarto, octavo, &c. have been exclusively devoted to the topographical history of London: but all are imperfect and unsatisfactory: the largest works being mostly tedious, trivial, and prolix; and the smaller publications are very superficial and inaccurate. At the end of this account will be given a list of several of these works; to point out the sources of the present

essay, and to furnish the reader, who may require more circumstantial information, with a guide to facilitate his researches. The following article will comprehend a general view of the history and local characteristics of this metropolis, with some particular descriptions; but for detailed accounts of many buildings, places, and objects, the reader is referred to the following heads, in different parts of this work: BANK of England, BRIDEWELL, BRIDGES, COMPANY, list of 91 in London, and accounts of the principal; COLLEGE of Civilians, or Doctors-Commons, COLLEGE of Heraldry, COLLEGE of Physicians, COLLEGE, Sion, COLLEGE of Surgeons, COLLEGE, Veterinary, ROYAL EXCHANGE, CUSTOM of London, DOCKS of London, EXCISE, FLEET-PRISON, GRESHAM COLLEGE, GUILDHALL, HOSPITALS of Bethlehem, Bridewell, Christ, and Foundling, INNS of Court, INSURANCE Companies, ISLINGTON, LAMBETH, HACKNEY, MARY-LE-BONE, PADDINGTON, MIDDLESEX, SURRY, NEWINGTON-BUTTS, THAMES, POLICE, PARLIAMENT, NEW-RIVER, LIMEHOUSE, STRATFORD-LE-BOW, SOUTHWARK, WESTMINSTER.

The centre of London, or St. Paul's church, is ascertained to be in latitude $51^{\circ} 31' N.$, and in longitude $5^{\circ} 37' W.$ of Greenwich, where the royal national observatory is established. The distance of London from the principal cities of Europe is as follows: from Edinburgh 395 miles S.; from Dublin 338 S.E.; from Amsterdam 190 miles W.; from Paris 225 miles N.N.W.; from Copenhagen 610 miles S.W.; from Vienna 820 miles N.W.; from Madrid 860 miles N.E. by E.; from Rome 950 miles N.N.W.; from Constantinople 1660 miles; from Moscow 1660 miles E.S.E.; from Stockholm 750 miles; from Petersburg 1140 miles; from Berlin 540 miles; and from Lisbon 850 miles.

London, as considered in the aggregate, comprises the city and its liberties, with the city and liberties of Westminster, the borough of Southwark, and nearly thirty of the contiguous villages of Middlesex and Surry. The greatest portion is built on the northern bank of the Thames, or in Middlesex; whilst Southwark, with Lambeth, and several connecting villages, extend along the southern shore of the same river, in the county of Surry. The extent of London, from west to east, or from Knightsbridge to Poplar, is full seven miles and a half; whilst its breadth, from north to south, or from Newington Butts to Islington, is nearly five miles. The circumference of the whole, allowing for various inequalities in the extension of streets, &c. at the extremities, cannot be less than thirty miles. Hence it may be fairly estimated, that the buildings of this metropolis cover at least eighteen square miles, or 11,520 square acres. Out of this must be deducted the space occupied by the river Thames, which extends about seven miles, or 12,320 yards in length, by one quarter of a mile, or 400 yards in width; making 1120 square acres.

Independently of various local and civil divisions, London may be said to consist of five distinguishing parts, or popular portions; viz. the west end of the town, the city, the east end of the town, Westminster, and the Borough. The "west end of the town," extending from Charing-Cross to Hyde-park, and from St. James's park to Paddington, is considered the best and most fashionable part of the town, and is laid out in the two great thoroughfares, called Oxford road and Piccadilly, with various handsome squares and streets, which are chiefly occupied by the town-houses of the nobility and gentry, and the most fashionable shops. The "city" includes the central part, and most ancient division of the metropolis. This is the emporium of com-

merce, trade, and business; and is occupied by shops, warehouses, public offices, and houses of tradesmen and others connected with business. The "east end of the town," and its inhabitants, are devoted to commerce, to ship-building, and to every collateral branch connected with merchandize. This division of London has assumed a novel character since the commencement of the present century, by the vast commercial docks and warehouses that have been formed and constructed here. The southern bank of the Thames, from Deptford to Lambeth, bears some resemblance to the east end of the town; being occupied by persons engaged in commercial and maritime concerns; docks, wharfs, and warehouses being abundant. But this part of London has one distinguishing feature from any other, as it abounds with numerous and various manufactories; iron-founderies, glass-houses, soap-boilers, dye-houses, boat-builders, shot and hat manufactories, &c. and many other similar establishments. From the great number of fires employed in these houses, and offensive effluvia arising from some of the works, this district is rendered extremely unpleasant, if not unhealthy, for human residence. It is therefore mostly inhabited by workmen, labourers, and the lower classes of society. Many improvements have lately been made, and several respectable houses erected on St. George's fields. In Westminster are the houses of lords and commons, the courts of justice, and many offices belonging to government. Another part of the metropolis, not hitherto noticed, but which may be considered as the last enlargement, and the most regular and systematic in its arrangement of squares, streets, &c. is the northern side of the town; comprehending a large mass of new buildings between Holborn and Somers-town, and in the parishes of Mary-le-bone and Paddington. Nothing shews the increased and increasing growth of the English metropolis more decisively than the vast number of new squares, streets, rows, and places, that have been recently erected, and are now in the progress of building, all round the metropolis. London is computed to contain nearly 70 squares, and 8000 streets, lanes, rows, courts, &c. According to a census obtained in the year 1811, the population of London, Westminster, and their suburbs, was 1,099,104 persons; being an increase of 133,139 within the course of ten years. Well might Cowper exclaim,

"Opulent, enlarged, and still increasing London."

It would be both amusing and interesting to trace the progressive growth or expansion of London; to describe it at different and remote periods; and delineate, with a careful and accurate pencil, the natural and artificial, the political and civil, the moral and commercial characteristics of the British metropolis, at different epochs. Some of these features will be noticed in the progress of our survey; but many must necessarily be omitted, from the peculiar nature of the present publication.

Ancient History and Antiquities of London.—It is generally admitted by topographers, that the present site of London was occupied as a British town before the arrival of the Romans. Of this, however, there is no evidence: for Geoffrey of Monmouth is not to be trusted, nor is his assertion entitled to respect. We are informed by Tacitus, that about the year 61, Londinium, or Colonia-Augusta, "was the chief residence of merchants, and the great mart of trade and commerce, though not dignified with the name of a colony." (Ann. lib. xiv. c. 33.) Boadicea, the amazonian queen of the Britons, headed a large body of natives, and, after conquering Camalodunum and Verulam, took posses-

tion of Londinium. At this time, it appears that Londinium was not fortified in the Roman manner, and was inferior to either of the other places just named. In a few years afterwards, the Romans made it a permanent station; surrounded it with a fortified wall of stone and brick, and governed the inhabitants by Roman laws. The course and extent of the walls were as follows: commencing at a fort, near the present tower of London, the wall was carried in a line directly north to Ald-gate; thence it made a curve to the south-west, to Bishops-gate, from which it continued in a straight line to Cripple-gate and Alders-gate; here it turned to the south, and proceeded to New-gate, where it made almost a right angle, turning to the south, to Lud-gate, and on to the banks of the Thames. The circuit of this part of the boundary, according to Stow, was nearly two miles and one furlong. Another wall, of about one mile in length, extended along the northern bank of the Thames, from the fort near the Tower to another fort near the present Black-friars bridge. These walls were defended, at different distances, by strong towers and bastions. The height of the wall is said to have been 22 feet, and the towers 40 feet. The superficial contents of the area thus enclosed have been computed at about 400 acres. Nearly through the middle of this station passed a stream, since called Wall-brooke. Dr. Stukeley, in his "Itinerarium Curiosum," has given a plan of Londinium, shewing the extent and form of the station, with the number of gates in the walls, and the military roads that branched off from it. The burial-places were without the walls, on the north and eastern sides of the town. Londinium was advanced from a *prefecture*, i. e. a town governed by a Roman præfect, to the rank of a colony. It also became the seat of the vicarius Britanniarum, and of the commissioners of the treasury under the Roman emperors. To enter into accounts of all the various remains of the Romans, which have been discovered at different times within the limits of London, would lead us into a long dissertation: it must suffice to state, that tessellated pavements, urns, coins, pottery, foundations of buildings, and other evident relics of the Romans, have been frequently found beneath the present surface. At the Bank, near the India house, and in Lombard street, some pavements have been taken up; and in various other parts of the city have been found evident traces of Roman habitations, and Roman customs. The London stone in Cannon street is considered, by most antiquaries, as part of a Roman milliare. These are all particularly described in Brayley's Survey of London and Middlesex, vol. i. 1810.

Very little is known of London during the Anglo-Saxon dynasty; nor do we know of any buildings, or other local antiquities, which may be referred to that period. Under the Saxons, London, then called Lunden, Lundone, Lundenburg, Lundenes, Lundencaester, gradually increased in extent and affluence; and, according to Bede, it then became the "emporium of many nations." Religious edifices were erected in the seventh century, on the sites of St. Paul's and Westminster Abbey. It is presumed there was a bridge across the Thames, near Westminster, previous to the year 994: as William of Malmesbury, when speaking of the repulse of the Danes under Sweyn and Olaf, says that "part of them were drowned in the river, because, in their hasty rage, they took no heed of the bridge." In the time of king Athelstan, a law was passed respecting coinage, by which it is specified that London was allowed eight minters, whilst only seven were appointed for the cities of Canterbury and Winchester.

Soon after the Roman conquest, a fortress or castle was built on the banks of the Thames; and this was enlarged

by Gundulph, bishop of Rochester, who erected the White tower, within the Tower of London. In the same reign St. Paul's church was commenced; and the strong castles of Baynard and Montfichet, both of them standing on the banks of the Thames within the city walls, were erected by two of the Norman king's officers, named Baynard and Montfichet. During this and several succeeding reigns, the public buildings of London were greatly augmented in number, by the erection of several religious edifices, abbatial and episcopal residences. The royal palace at Westminster, which had been founded by Edward the Confessor, was considerably enlarged; and a large hall was built there by William Rufus. The reign of Henry I. was distinguished by the foundation and construction of many monastic houses; and several others were established during the Anglo-Norman and Plantagenet dynasties.

A list of the religious houses, with the time of their different foundations, will afford a tolerable idea of the gradual increase of the city, with respect to such establishments, and of the difference between ancient and modern London. The town appears to have contained no less than fifty-four monastic houses, such as abbies, priories, nunneries, hospitals, colleges, &c.

St. Paul's cathedral was first founded by Ethelbert, king of Kent; church rebuilt in 961; again in the time of William Rufus. The present church commenced in 1675.

The priory of St. Martin-le-Grand, founded by Withred, king of Kent, in the year 700; was given, in 1502, by Henry VII. to Westminster Abbey; the street of St. Martin-le-Grand is still annexed to Westminster.

The nunnery in Clerkenwell, founded in 1100, by sir Jordan Briset.

The hospital of St. John of Jerusalem, in Clerkenwell, was founded in 1100, by the same.

The Holy Trinity, or Christ-church, within Ald-gate, was founded by the empress Maud, in 1108, for Austin canons.

The priory of St. Bartholomew in West Smithfield was begun by Rahere, in 1123; the hospital soon afterwards.

A Benedictine nunnery of Haliwell, by Robert Fitz-Gelran, before 1127.

St. Katherine near the Tower, by the empress, before 1148.

The Old Temple of Holborn, in 1118; and the new one near Fleet-street, by the order, in 1185.

St. Mary Spittle, by Walter Brune, in 1197.

St. Thomas of Acre, in the end of Henry II.'s reign, by Thomas Fitz-Theobald.

The college of Allhallows Barking, by Richard I.

The nunnery of St. Helen's, in Bishops-gate-street, was founded by William Fitz-William, in 1210.

The Black Friars had a house near Chancery-lane, but afterwards begged or bought the ground near Castle Baynard, soon after 1221.

The Grey Friars, about 1224; afterwards in Newgate street.

The White Friars, by sir Rich Grey, in 1241.

A priory for Austin Friars was established in Broad-street, by Humphry Bohun, earl of Hereford, in 1253.

The Friars of the Sack, Old Jewry, 1257. Order dissolved, 1307.

The Crossed or Crutched Friars, by Ralph Hosier and William Saberns, in 1298.

The Rolls, or Domus Conversorum, by Henry III. in 1231, for the conversion of Jews.

St. Mary Rouncivall in the Strand, about the same period.

The hospital or priory of St. Mary of Bethlem or Bedlam, was granted by Simon Fitz-Mary, in 1247.

The convent of St. Clare, in the Minorics, by Edmund earl of Lancaster, in 1293.

A college and hospital, called Elsing Spittle, were founded by William Elsing, a citizen, in 1329.

Sir John Pountney founded a college in Cannon-street, in 1332.

St. Mary of Graces, or East-Minster, a Cistercian abbey, was founded by king Edward III. in 1350.

The Charter-House, before 1370, by sir Walter de Manny, and Michael de Northburgh, bishop of London. See CHARTREUSE.

The hospital of the Savoy, in 1505, by Henry VII.

Besides these, the guilds or fraternities of London were very numerous. There was a brotherhood and chapel of the Holy Trinity in Leadenhall, and several others were founded in most churches. The grand suppression of the whole commenced in 1537. Exclusive of the religious houses, the bishops and parliamentary abbots had each a town residence of state.

The abbot of St. Aspin's, Canterbury, house was in the parish of St. Olave's, Southwark.

The abbot of Lvesham's, in the parish of St. Catherine Cree.

The abbot of Reading's, at Baynard castle, in the parish of St. Andrew Wardrobe.

The abbot of St. Mary's, York, at St. Peter's Place, Paul's Wharf.

The abbot of Glastonbury, in West Smithfield.

The abbot of Hyde, in the parish of St. Mary at Hill.

The abbot of Ramsey, in Whitecross-street.

The abbot of Bury St. Edmund's, in St. Mary-street, Aldgate.

The abbot of St. Alban's, in Lothbury.

The abbot of Peterborough, in the parish of St. Gregory.

The abbot of Salop, near St. Bartholomew's, West Smithfield.

The abbot of Leicester, in the parish of St. Sepulchre.

One instance of the service which was rendered to the public, even in London, by the monastic institutions, is worthy of note: the priory of St. Mary Spittle contained, at its dissolution about the year 1536, no less than 180 beds for the reception of sick persons and travellers. The hospitals which were suffered to remain, owed their continuance to sir Richard Gresham, mayor of London, in 1537, who petitioned the king to bestow the lands belonging to this, St. Bartholomew's, St. Thomas's, and the new abbey on Tower-hill, on the corporation, for the relief and use of the poor, the sick, and the vagrant.

Annals of London, from the Departure of the Romans to the Accession of Edward I.—When the Romans, from the distracted state of the empire, found it necessary, in the early part of the fifth century, to withdraw their troops from the distant provinces, London again became a British town, and is mentioned in the Saxon chronicle in the year 457, when the Britons fled thither on their defeat by the Saxons under Hengist, who, about twenty years afterwards, made himself master of London; but on his death, in 498, it was retaken by Ambrosius, and retained by the Britons during a considerable part of the next century. It afterwards became subjected to the newly-established Saxon kingdom of Essex. On the conversion of the East Saxons to Christianity, London was nominated as the bishop's see, Melitus being appointed the first bishop in the year 604: a cathedral church

was erected in 610, on the site of the present St. Paul's. During the period of the Saxon heptarchy, but few notices of London appear to have been recorded. In 664 it was ravaged by the plague; and in 764, 798, and 801, it suffered severely by fires; in that of 798 it was almost wholly consumed, and great numbers of the inhabitants perished. On the union of the Saxon kingdom under Egbert, London, though not the royal residence, or seat of government, as has been erroneously stated, was advancing in consequence, as appears from a Wittenagemot having been held here in 833, to consult on proper means to repel the Danes. By these invaders London was repeatedly pillaged and laid waste. In 925 king Athelstan had a palace here; the city increased in importance under the Danish sovereigns, and under Edward the Confessor; and on the successful invasion of William the Conqueror, the magistrates of London, conjointly with the prelates and nobility, invited him to accept the title of king of England. From this period London may be considered as the metropolis of the kingdom.

William, at the commencement of his reign, granted a charter to the citizens, which is beautifully written in the Saxon characters, and is still preserved among the city archives: it consists of only five lines on a slip of parchment, six inches long and one broad. In the year 1077 the greater part of the city was destroyed by fire. In the following year the king founded the fortress, now called the White Tower, for the purpose of keeping the citizens in awe, as he had reason to suspect their fidelity. In 1086 another fire consumed the principal part of the city, together with the church of St. Paul. Maurice, then bishop of London, laid the foundation of the new church: "a worke," Stow observes, "that men of that time judged would never have been finished, it was then so wonderful." It is remarkable that Domesday book, though so minute in regard to other cities and towns, does not contain any notice of London. A vineyard is mentioned in Holborn belonging to the crown, and ten acres of land near Bishopsgate (now the manor of Norton-Falgate) belonging to the dean and chapter of St. Paul's. In November, 1090, above 600 houses and several churches were blown down by a tremendous hurricane, and Stow says, "the Tower of London was also broken." About two years afterwards another destructive fire happened. In the succeeding years William Rufus repaired the Tower, and strengthened it by additional works; and in 1097 he built a great hall at Westminster. Henry I., as a reward for the ready submission of the Londoners to his usurped authority, granted to the city an extensive charter of privileges, among which was the perpetual sheriffwick of Middlesex. On the death of Henry, the Londoners took a decided part in favour of Stephen in his contest with the empress, and greatly contributed to his establishment on the throne. In the first year of his reign a fire, beginning near London Stone, consumed all the houses eastward to Aldgate, and westward to St. Paul's, together with London bridge, which was then of wood. Henry II. does not appear to have held the citizens in any great degree of favour, probably resenting their attachment to Stephen: and we find that large sums of money were extorted from them under the specious name of Free-gifts. In 1176 the building of a new bridge of stone was commenced at London, but was not completed till the year 1209. On the coronation of Richard I. a dreadful massacre of the Jews, who were settled in London, was made by the brutal and ignorant populace. At the coronation-dinner, the chief magistrate of London, who at that time had the title of bailiff, acted as chief butler. Early in this

When the appellation was changed to that of mayor, in the person of Henry Fitz Alwyn. Richard granted the city a new charter, confirming all its liberties, with additional privileges; and four years afterwards, on payment of 1500*l.* he granted another, providing for the removal of all weirs that had been erected on the river Thames; on this charter the corporation of London found their claim to the conservatorship of that noble stream. In 1196, a sedition arose in London, headed by William Fitz Osbert, who excited the common people to oppose the government, and gained associates to the amount of 50,000; but the leader being taken and executed, the commotion subsided. This is one of the first instances upon record of a tumultuous assemblage in defence of popular rights. In the reign of king John the civic importance of London was greatly increased; and its corporation finally assumed that form and predominancy, which, with a few alterations, it has maintained till the present time. John granted the city several charters; by one he empowered the "barons of the city of London" to choose a mayor annually, or to continue the same person from year to year, at their own pleasure. In 1212 a dreadful calamity took place, through a fire which commenced at the bridge end in Southwark, and occasioned a destruction almost unparalleled from such a cause: Stow relates that about 3000 persons perished. During the contest between the king and pope Innocent III. London severely felt the consequences of the interdict which was laid upon the kingdom. In the civil feuds, which marked the latter years of John, the Londoners sided with the barons; and when the humbled monarch was compelled to sign Magna Charta, it was therein expressly stipulated that the "city of London should have all its ancient privileges and free customs as well by land as by water." The long reign of Henry III. affords but few events worthy of notice respecting London: its growing prosperity was checked by a series of extortions and oppressions. In 1258, the price of corn was so excessive, that a famine ensued, and according to the chronicles of Evesham, 20,000 persons died of hunger in London only. In 1264 another massacre of the Jews took place; on a plea that one of that persecuted race had taken more than legal interest, and upwards of 500 Jews were put to death by the populace, and their houses and synagogues destroyed.

Annals of London from the Accession of Edward I. to that of Henry IV. In the year 1279 all the Jews in England were apprehended in one day, on a charge of their being the authors of the great mutilations which had taken place in the coin during the preceding reign: 280 persons of both sexes were executed in London, besides many others in various parts of the kingdom. Between the years 1314 and 1317 the city, in common with the rest of the kingdom, suffered greatly from a scarcity of provisions, which eventually produced a complete famine. King Edward III., on the commencement of his reign, granted to the city two charters: by the first all the ancient privileges were confirmed and additional ones bestowed; by the other, the village of Southwark was granted to the citizens in perpetuity. In 1348, the terrible pestilence, which, breaking out in India, spread itself westward through every country on the globe, reached England. Its ravages in London were so great, that the common cemeteries were not sufficiently capacious for the interment of the dead; and various pieces of ground without the walls were assigned for burial places: amongst these was the waste land now forming the precinct of the Charter-house, where upwards of 50,000 bodies were then deposited. This destructive disorder did not entirely subside till 1357. The public entry of Edward the

Black Prince into London, May 24, 1356, after the victory he obtained at Poitiers, was celebrated with an unparalleled degree of splendour; and every street through which the cavalcade passed, exhibited an extraordinary display of riches and magnificence. The captive king of France, dressed in regal robes, was mounted on a white courser, while the victorious prince rode by his side on a small black horse, and appeared more like an attendant than a conqueror. In 1361, the plague having again broke out in France, every precaution was taken to prevent its spreading into England, but without effect; the pestilence reached London, and its ravages were so destructive, that upwards of 2000 persons fell victims in two days. In 1363, a sumptuous entertainment was given in the city by Henry Picard, alderman, to the kings of England, France, Scotland, and Cyprus, to Edward the Black Prince, and to a great number of nobility and gentry. The year 1378 is memorable in the city annals for the expedition fitted out by an individual, John Philpot, against Mercer, the Scottish pirate, who taking advantage of the inattention of government to naval affairs, carried off all the shipping from the port of Scarborough; and continuing to infest the northern coast, frequently made considerable prizes. The complaints of the merchants were but little regarded by the council; when Philpot prepared a fleet at his own expence, with a thousand men well armed, went himself on board as commander-in-chief, and failed in pursuit of the pirate. A long and desperate engagement ensued; but Philpot obtained the victory, and obliged the pirate to surrender, with most of his ships, among which were fifteen Spanish vessels richly laden. In November 1380, the fourth year of Richard II. an act of parliament was passed for levying a poll-tax on every person in the kingdom, male or female, above the age of fifteen years. This act was the occasion of producing, in the following year, one of the most dangerous insurrections that ever threatened the monarchy of this kingdom; and in which the metropolis particularly suffered. The tax was exacted with great rigour; and the insolence of the collectors was an additional cause of irritation, and kindled the sparks of sedition which soon after burst into an open flame. The insurrection began in Essex, but quickly spread through the neighbouring counties, and particularly in Kent, where the daughter of Wat Tyler, so called from his trade, having been indecently treated by a collector, the father killed him, and being supported by the insurgents, placed himself at their head. To his standard incredible numbers flocked from all parts of the kingdom; and on the 10th of June, 1381, having mustered on Blackheath a hundred thousand strong, they entered Southwark, where they set at liberty the prisoners from the King's Bench and Marshalsea prisons, and levelled the houses of all lawyers. They burnt the archbishop's palace at Lambeth, with the rich furniture, books, and registers, and destroyed the public stewes which were then tolerated on Bankside. For one day the bridge gate was shut against them; but they were afterwards, from prudential motives, admitted into the city. They then proceeded to the palace of the Savoy, which was one of the most magnificent structures in the kingdom. Having set fire to it in several places, they caused proclamation to be made, that no person should convert any part of the rich effects to his own use, and actually threw into the fire one of their companions who had reserved a piece of plate. They also burnt the Temple and the other mans of court. Dividing into three parties, one advanced to the rich priory of St. John of Jerusalem, near Smithfield, which they burned; a second division marched to the Tower, where they seized sir Robert Hales, lord treasurer, and Simon

Sudbury, archbishop of Canterbury, and lord chancellor (though guarded by 1200 soldiers), and hurrying them to the adjacent hill, beheaded them; the third division proceeded to Mile End, where the king met them, and promised to redress their supposed grievances, on which they dispersed. But Wat Tyler, with his party, under the pretence of reforming abuses, continued their ravages in London, liberated the prisoners from the Fleet and Newgate, plundered the houses of the Lombards who resided in the street, which yet retains their name, and dragging the merchants from the churches, whither they had fled for refuge, beheaded them in the streets. Not content with murdering many of the most eminent citizens, they made proclamation for beheading all lawyers and persons connected with the Exchequer, and even, all who, in those days of ignorance, were capable of writing. The king made another effort for negotiation: attended only by forty horse, he met Tyler with 20,000 of his adherents in Smithfield. The behaviour of Tyler was so insolent, that the king ordered the mayor, sir William Walworth, to arrest him; on his resistance, sir William felled him to the ground with his sword, and the attendants dispatched him. The rebels prepared to revenge their leader's death; but Richard, though only fifteen years of age, with a prudence and bravery which did him more credit than any other action of his life, rode forward, exclaiming, "My friends, will you kill your king? Be not troubled for the loss of your leader; I will be your captain, and grant what you desire." They then marched under his direction to St. George's Fields, where, finding a thousand citizens completely armed to oppose them, they threw down their weapons, obtained their pardon, and immediately dispersed. Thus ended an insurrection unparalleled in the annals of this kingdom, and which for three weeks seemed to threaten a total subversion of the government. In 1390, the king appointed a tournament to be held in London, and sent heralds to proclaim his intention to all the principal courts of Europe, whence many princes and nobles came to attend the spectacle, which was continued with the greatest splendour for four days; open house being kept at the king's expence for all persons of distinction. The vast expenditure which this and similar festivities occasioned, frequently reduced Richard to great pecuniary difficulties; his enormous profusion led him to a system of oppression and extortion, which eventually caused his deposition and death.

Annals of London from the Accession of Henry IV. to that of Elizabeth.—At the coronation of the new king, the mayor, as usual, officiated as chief butler. The citizens were gratified by the repeal of some obnoxious statutes, and an extension of their privileges. In 1401, an act was passed for "burning obstinate heretics," entirely aimed at the Lollards, or followers of Wickliffe. The first victim was William Santer, parish priest of St. Osyth, in Syth-lane, London. In 1407, the Plague again ravaged the kingdom, and swept away more than 30,000 of the inhabitants of the metropolis. In 1409, "a great play, of Matter from the Creation of the World," was acted at Skinner's-Well, near Clerkenwell. The exhibition lasted eight days; at which were present the king and most of the nobility and gentry of the realm. In the following year, John Bradley was condemned as a Wickliffite, and burnt in Smithfield, with circumstances of peculiar cruelty. In this year Guildhall was erected; the city hall before being a mean cottage in Aldermanbury. The return of king Henry V. after the glorious victory obtained at Agincourt in 1415, was celebrated in London with great magnificence. Neither this reign nor the following produced any events of peculiar import to the city, till the year 1450, when a new insurrection arose, of so formidable a

nature, that for some weeks all the power of the crown was insufficient to quell it. This tumult is supposed to have been raised by the instigation of the duke of York, in order to sound the inclination of the people, and prepare the nation for his design of seizing that sceptre which Henry swayed so feebly. By the secret instructions of the duke, Jack Cade, who had served under him in the French wars, assumed the name of Mortimer, and collected a strong body of malcontents, under the popular pretext of redress of grievances. They entered the city in triumph, and for some time bore down all opposition; and beheaded the lord treasurer, lord Say, and several other persons of note. The insurgents at length losing ground, a general pardon was proclaimed, and Cade, finding himself deserted by his followers, fled: but a reward being offered for his apprehension, he was discovered, and refusing to surrender, was killed. The remainder of this reign was filled up with the dreadful contest between the Lancastrians and Yorkists, which ended in the deposition of Henry and the establishment of Edward IV. on the throne. The year 1472 will ever be memorable in the annals of the metropolis, for the introduction of printing into this country by William Caxton, citizen and mercer. The history of the kingdom during this reign and that of Richard III. does not in any particular manner affect the concerns of the city. Soon after the accession of Henry VII. in 1485, an epidemical disorder of a very singular nature, called the *sweating sickness*, raged with great violence in London. Those attacked by it were thrown into a violent perspiration, which generally occasioned their death within twenty-four hours. It appears from Hall's Chronicle, that two mayors and six aldermen died of this complaint in one week. This reign was particularly marked by oppression and extortion on the part of the king; and the tumults and insurrections occasioned thereby, particularly that in support of Perkin Warbeck, who was asserted to be Richard, duke of York, and the heir to the throne. In this event, though highly interesting to the kingdom, the city was not immediately concerned. In 1500 the kingdom was again visited by the Plague, of which 30,000 persons died in the metropolis and its vicinity. In the reign of Henry VIII. when he attempted to raise money without the aid of parliament, the citizens made such determined opposition to the measure, and their example had such an influence through the kingdom, that the king, in full council, abandoned his design, and granted a pardon to all who had opposed him. On the king's marriage with Anne Boleyn, in 1533, she was conveyed from Greenwich to the Tower, and thence through the city to Westminster, with all the magnificence and pageantry which unbounded prodigality could devise. The remainder of this reign was notorious for the tyranny and cruelty of the king, who, having thrown off the pope's supremacy, sacrificed all who adhered to it; yet professing a zealous attachment to the doctrines of the church of Rome, he put to death those persons who presumed to differ from him. Hence the promoters of reformation, and its opposers, perished in the same flames; the blood of the Catholic and Protestant was shed upon the same block; and Henry, whilst vehemently contending against the pope's infallibility, supported his own with the most vindictive cruelty. In these sanguinary scenes, London had its full share; great numbers, of all ranks, were continually executed, either for heresy or treason. The suppression of the monasteries now took place: opposition to the king's will was fatal; and the partial insurrections which broke out in consequence, only served to forward his measures, by giving the colour of necessity to the vengeance that was inflicted. Many improvements were made during this reign in the city and its

suburbs. The police was better regulated; nuisances were removed; the streets and avenues were amended and paved; and various regulations were carried into effect for supplying the metropolis with provisions, to answer the demands of an increasing population. In the short reign of Edward VI. the reformation proceeded with steadiness and regularity; but on the accession of Mary the church of Rome again gained the ascendancy. On the projected union between the queen and the king of Spain, a formidable insurrection ensued, in which the city was particularly affected: the suppression of this revolt was followed by a dreadful scene of sanguinary triumph. The statutes against heretics were now also enforced with great severity. A number of persons were burnt in Smithfield: in the whole kingdom upwards of 200 were brought to the stake.

Annals of London from the Accession of Elizabeth to the Revolution in 1688.—Elizabeth succeeded her sister amidst the acclamations of all ranks of people. Reformation again reared its head, and was in a short time firmly established. In 1561 the spire of St. Paul's cathedral was struck by lightning, and great part of the building consumed. In 1563 the Plague again made dreadful ravages, to which 20,000 persons fell victims in the city. In July 1566, the foundations of the Royal Exchange were laid by sir Thomas Gresham, and the structure was completed in the following year. The year 1569 exhibited a novelty in London of most pernicious example. The first public lottery was then drawn at the west door of St. Paul's cathedral, and the drawing continued, without interruption, from January 11 to May 6. The prizes were of plate, and the profits were appropriated to the repair of the sea-ports. In 1586 a conspiracy was set on foot to assassinate Elizabeth, and free the queen of Scots from the captivity in which she had passed almost eighteen years. The plot was soon discovered, and the conspirators, fourteen in number, were executed in Lincoln's-Inn-Fields. Mary was said to be implicated in the conspiracy; and this, whether true or false, furnished a plausible pretext for those proceedings, which soon after condemned her to the block. The sentence against her was proclaimed with great solemnity at different places in London and Westminster. In the preparations made to repel the threatened attack of the boasted Spanish Armada, London took a most distinguished share, in furnishing large supplies of money, men, and ships. The preparations for the coronation of king James were interrupted by a dreadful Plague, which ravaged the city with greater violence than any similar visitation since the time of Edward III. In 1604, the horrible conspiracy, known in history by the name of the "Gunpowder Plot," the grand object of which was to prepare the way for the restoration of the Catholic religion, was commenced by its daring contrivers, with every possible precaution that seemed necessary to ensure its success. The destruction of the king and parliament was the preliminary measure through which the conspirators thought to accomplish their design; and the blowing up of the parliament-house with gunpowder at the moment when the sovereign should be commencing the business of the session by the accustomed speech from the throne, was the dreadful means by which the destruction was intended to be accomplished. All the principal conspirators were bigotted Catholics, who had for many years been plotting the downfall of Protestantism in this country, and had even applied for aid to Spain and Flanders. Being disappointed of the assistance they required, they resolved to depend on their own efforts, and about Easter 1604, formed the idea of the gunpowder plot, to be carried into effect on the meeting of parliament in February

following. Accordingly Percy, one of the conspirators, hired a house immediately adjoining to the house of lords, and the operations commenced by digging through the foundation-wall, which was nine feet in thickness. Just at this juncture, a vault under the parliament-house, used as a depository for coals, was to be let, and the coals to be sold. As nothing could have happened more favourable for their purpose, Percy hired the cellar, and bought the coals, as if for domestic use, and without any appearance of concealment. The prorogation of parliament from February to October gave the conspirators sufficient leisure to further their design; and, at convenient opportunities, thirty barrels and four hogheads of gunpowder, which had been procured from Holland, were conveyed into the cellar by night, and covered with billets, faggots, iron-bars, and stones. This was done without exciting any suspicion: parliament had again been prorogued to November 5th; and the conspiracy wore every aspect of success. It had now been on foot eighteen months, and confided to more than twenty persons; yet nothing had led a single step towards discovery; when the plan was happily frustrated by a circumstance apparently trivial. One of the conspirators, wishing to save lord Monteagle, sent him a letter, advising him, in ambiguous terms, to absent himself from parliament, on account of a sudden danger to which he would be exposed. This notice Monteagle carried to the secretary of state, who laid it before the privy-council. A secret search was determined on, but, to prevent suspicion, was delayed till the eve of the meeting of parliament, and then made only by the lord chamberlain, as if in a formal discharge of his office. When he entered the cellar, and saw the great store of coals and wood, he enquired to whom it belonged, and was informed the cellar was let to Mr. Percy, and the fuel was for his consumption. The chamberlain heard this with seeming carelessness, and left the cellar with apparent negligence. But at midnight a further search was made; Guy Fawkes, a principal conspirator, to whom the final execution of the plot was assigned, was apprehended in the cellar: the fuel was removed, and the gunpowder discovered. Fawkes gloried in the plot, but refused to discover his accomplices; the sight of the rack, however, subdued him, and he made a full disclosure of the whole conspiracy. His associates fled into Warwickshire, where they endeavoured to excite a rising of the Catholics, but without effect. A proper force was sent against them, four were killed in resistance, and the rest were taken and brought to London, where, with Fawkes, they suffered the just punishment of their guilt. In the year 1609, the city acquired a considerable accession of power and property: almost the whole province of Ulster, in Ireland, having fallen to the crown, the king made an offer of the escheated lands to the city, on condition they would establish an English colony there. The proposal was accepted; and so rapid was the colonization forwarded, that within seven years arose the two capital towns of Londonderry and Coleraine. The commencement of Charles I.'s reign was marked by the return of the plague, which carried off in the metropolis 35,000 persons. To advert to all the important transactions that took place in London during the eventful struggle between Charles and his people would far exceed our limits. The excessive oppressions to which the nation was subjected, were more particularly felt in the metropolis than in other parts of the kingdom, from its being more directly within the vortex of the star-chamber and high-commission courts, and from the effects of the monopolies, which had a most pernicious influence on trade and

commerce. For the particulars of this important period, we refer our readers to Clarendon's History of the Great Rebellion.

The year 1665 became memorable in London by the dreadful ravages of the great Plague, which first made its appearance in December 1664, and had not entirely ceased till January 1666. Its progress, the first two or three months, was comparatively small, but continued to advance, notwithstanding every precaution was used to abate its fury: from May to October 1665, it raged with the greatest violence; the deaths progressively increased from five hundred to eight thousand weekly. The pestilence was now at its height: its ravages, which commenced in Westminster and the western suburbs, extended through the city to Southwark, and to all the parishes eastward of the Tower. The digging of single graves had long been discontinued, and large pits had been excavated, in which the dead were deposited with some little regularity and decent attention: but now all regard to ceremony became impossible. Deeper and more extensive pits were dug, and the rich and the poor, the young and the aged, the adult and the infant, were all promiscuously thrown together into one common receptacle. Whole families, and even whole streets of families, were swept away together. By day, the streets presented a most frightful aspect of desolation and misery; and at night the dead carts, moving with slow pace by torch-light, and with the appalling cry, "Bring out your Dead," thrilled horror through every heart that was not by suffering hardened to calamity. The stoppage of public business was so complete, that grass grew within the area of the Royal Exchange, and even in the principal streets of the city: all the inns of court were shut up, and all law proceedings suspended. The entire number returned in the bills of mortality, as having died of the plague within the year, was 68,950; yet there can be no doubt that this total fell short, by many thousands, of those who actually fell by the infection, but whose deaths were not officially recorded. The aggregate is estimated at about 100,000. The whole number of deaths within that year, as given in the bills, was 97,306. Since this dreadful period, the plague has entirely ceased in London: a circumstance that must be regarded as the more remarkable, when it is considered how frequent had been its ravages for ages past, and when reference is had to the bills of mortality for the preceding part of this very century, when scarcely a year passed without some persons falling victims to the infection. For further particulars, see **PLAGUE**.

The most important event that ever happened in this metropolis, whether it be considered in reference to its immediate effects, or to its remote consequences, was the great Fire, which broke out in the morning of Sunday, September 2, 1666, and, being impelled by strong winds, raged with irresistible fury nearly four days and nights, nor was it entirely mastered till the fifth morning. The destructive extent of this conflagration was, perhaps, never exceeded in any part of the world, by any fire originating in accident. Within the walls it consumed almost five-sixths of the whole city; and without the walls, it cleared a space nearly as extensive as the one-sixth part left unburnt within. Scarcely a single building, that came within the range of the flames, was left standing. Public buildings, churches, and dwelling-houses were alike involved in one common fate; and, making a proper allowance for irregularities, it may fairly be stated, that the fire extended its ravages over a space of ground equal to an oblong square, measuring upwards of a mile in length, and half a mile in breadth. In the summary ac-

count of this vast devastation given in one of the inscriptions on the monument, and which was drawn up from the reports of the surveyors appointed after the fire, it is stated, that "the ruins of the city were 436 acres, *viz.* 373 acres within the walls, and 63 in the liberties of the city; that of the six-and-twenty wards it utterly destroyed fifteen, and left eight others shattered and half burnt; and that it consumed 400 streets, 13,200 dwelling-houses, 89 churches, besides chapels; four of the city gates, Guildhall, many public structures, hospitals, schools, libraries, and a vast number of stately edifices." The immense property destroyed in this dreadful conflagration could never be calculated with any tolerable degree of exactness; but according to the best estimations that have been made, the total value must have amounted to the immense sum of ten millions of pounds sterling. As soon as the general consternation had subsided, the rebuilding of the city became the first object of consideration; an act of parliament was passed for that purpose; and though all was not done that might have been, the city was principally rebuilt within little more than four years, and that in a style of far greater expence and regularity, and infinitely more commodious and healthful, than the ancient capital. In the system of tyranny and oppression which marked the reign of Charles II. the city largely participated; having its ancient liberties and privileges invaded, and magistrates arbitrarily forced on the citizen at the pleasure of the king. Every principle of law and justice was violated; and in this humiliating state London continued till the revolution.

Annals of London from the Revolution in 1688, to the present Time.—In the first year of William and Mary, an act was passed, by which all proceedings of former reigns against the city charters were reversed, and all the rights and privileges of the citizens were fully re-established. In 1692, during the king's absence in Holland, the queen borrowed 200,000*l.* of the city for the exigencies of government. In 1694, an infamous system of bribery was investigated by the house of commons, when it was proved, that a thousand guineas had been demanded and taken from the chamberlain of London by sir John Trevor the speaker, for forwarding the Orphan bill; in consequence of which he was expelled the house. In 1697, an act of parliament was passed for the suppression of the much abused privilege of sanctuary, heretofore attached to the following places, *viz.* the sanctuary in the Minories, Salisbury-court, White-friars, Ram-alley, and Mitre-court in Fleet-street; Fulwoods-vents in Holborn; Baldwin's-gardens in Gray's-inn-lane; the Savoy in the Strand; and Montague-close, Deadman's-place, the Clink, and the Mint, in Southwark. The year 1703 was remarkable for a dreadful storm of wind, which raged through the night of the 26th of November. The damage sustained by the city alone was estimated at two millions sterling; and in the suburbs the damage was proportionably great: the lead on the tops of several churches was rolled up like skins of parchment; and at Westminster-abbey, Christ's-hospital, St. Andrew's Holborn, and many other places, it was carried off from the buildings. The ships in the river were driven from their moorings; four hundred wherries were lost; more than sixty barges were driven foul of London-bridge, and as many more were sunk or staved above the bridge. At sea the destruction was immense; twelve men of war, with more than eighteen hundred men on board, were lost within sight of their own shore. The year 1709 was marked by a circumstance highly creditable to the humanity of the nation. The cruel depredations of the French in the palatinate compelled the inhabitants to

desert their country; twelve thousand, in the most forlorn condition, sought refuge in London: the queen, for some time, supported them out of her privy purse; she was afterwards assisted by the benevolence of her subjects, and 22,038*l.* was paid into the chamber of the city for the relief of these distressed fugitives, who were finally disposed of as colonists to Ireland and North America.

The increase in the population of the metropolis having occasioned a great insufficiency in places for divine worship, an act of parliament was passed in 1711 for erecting fifty new churches in and about London: the expence of which was defrayed by a small duty on coals brought into the port of London for about eight years. The year 1720 will ever be famous in the annals of London, from the destructive system of speculation and fraud which history has denominated the South Sea bubble; and which so completely infatuated the people, that they became the dupes of the most barefaced impositions. (See BUBBLE, in *Commerce*.) The directors of the South Sea Company, encouraged by the prevalent spirit of avaricious enterprise, proposed to the government to take into their fund all the debts of the nation, under the plausible pretext of a speedier redemption. The amount of the debts was 31,664,551*l.*; for the liberty of adding the whole of which to their capital stock, they offered to pay to the public the immense sum of 7,723,809*l.* This bait was too tempting to be refused; the plan received the sanction of parliament, and the directors were empowered to raise the ready money necessary for so great an undertaking, "by opening books of subscription, and granting annuities to such public creditors as were willing to exchange the security of the crown for that of the South Sea Company, with the advantage of sharing in the emoluments that might arise from their commerce." So much was the public mind impressed with the idea of rapid gain, that before the act received the royal assent, the company's stock rose to 319*l. per cent.*: it advanced so amazingly for three months, that books were then opened for a fresh subscription of four millions at 1000 *per cent.*; and such was the popular frenzy, that within a fortnight the new subscription was at 200 *per cent. premium*. Some alarm now prevailed: it had been whispered, that the directors and their friends had disposed of their own stock while the price was at the highest; and all confidence in the stability of their credit was destroyed. The confusion became general; every one was willing to sell, but no purchasers could be found, except at a vast reduction. Distraction and dismay spread through the city; the stock fell rapidly, and, before the end of the year, was reduced to 86 *per cent.* which was about its real value. The destruction to public and private credit, thus produced, was excessive: all trade was at a stand; and many of the most respectable merchants, goldsmiths, and bankers of London, who had unwisely lent large sums to the company, were obliged to abscond. A parliamentary investigation ensued; and the knavery of the directors was so apparent, that the greater part of their estates was confiscated for the benefit of those whom their villainy had ruined. The sum thus obtained amounted to 2,014,000*l.*

During the continuance of the infatuation which the South Sea delusion inspired into all classes of people, many other visionary projects were set on foot by speculators and gamblers; even chartered companies of established credit lent their countenance to schemes of impossible accomplishment: nearly two hundred subscription projects were afloat at one time. When the public confidence in the South Sea scheme was on the decline, the superior stability of the bank of England, East India, and African companies, was at once seen: Bank stock rose from 100 to 200; East India stock

from 100 to 405; and African stock from 100 to 200. The shares in the London and Royal Exchange Assurance Companies also experienced a prodigious rise. See *INSURANCE*.

The close of the year 1729 was attended by a great mortality in London; the deaths within the bills of mortality in the course of the year amounting to almost 30,000. The pernicious habit of dram-drinking had become so general, and so many disorders had been occasioned, and crimes committed in consequence of it, that in the year 1736 the legislature found it necessary to prohibit the selling of Geneva, except under certain restrictions. Previous to this, the magistrates had ascertained that the number of gin-shops in London and Westminster was 7044, besides garrets and cellars where the baneful liquor was sold privately. So determined were the retailers to carry on their trade, that the utmost exertions of the police were required to enforce the act; and within two years, 12,000 persons were convicted and fined under its provisions.

The winter of 1739—40 was memorable from the occurrence of one of the most intense frosts ever known in this country, and which is recorded in our annals by the appellation of the Great Frost; it commenced on Christmas-day, and lasted till the 17th of February: above bridge the Thames was completely frozen over, and numerous booths were erected on it for selling liquors, &c. to the multitudes who daily flocked thither. Great improvements were now made in different parts of the metropolis; and convenience, health, and safety, were more generally attended to than they had previously been. Westminster bridge was finished and opened for public use in the year 1750; the houses upon London bridge were pulled down in 1756; and in the two succeeding years the bridge was put into a course of repair. In 1760 Black-friars' bridge was commenced; most of the city gates were taken down; and an act of parliament was obtained for making alterations in the avenues of the city and its liberties; some of which have been carried into effect at different periods, yet many others remain to be executed. In the year 1763, the recent peace with France, the resignation of Mr. Pitt, afterwards earl of Chatham, as premier, and other political occurrences, set the metropolis into a complete ferment. The conduct of administration was such, as to augment rather than obviate the prevailing discontents. Hence the ministry were assailed with political publications; in particular by a periodical paper called "The North Briton;" the writers of which, the principal of whom was John Wilkes, were determined to expose the measures of the then administration to the contempt they deserved. The forty-fifth number of this paper contained such severe reflections on the king's speech to parliament, that the ministry thought they had an opportunity to crush their avowed enemy. Mr. Wilkes was apprehended and committed to the Tower under an illegal warrant, signed by the principal secretary of state; but the case being argued in the court of Common Pleas, before lord chief justice Pratt, the court directed him to be discharged. Mr. Wilkes brought actions against the earl of Halifax, secretary of state, for issuing the warrant, and against Mr. Wood, under-secretary, and obtained verdicts with damages; 4000*l.* from the former, and 1000*l.* from the latter. Shortly after his release, Mr. Wilkes established a printing-press in his own house, and republished all the numbers of the obnoxious paper. This provoked the ministry so highly, that an information was filed against him. The "North Briton, No. 45," was voted by the house of commons to be a seditious libel, and ordered to be burnt by the common hangman. Mr. Wilkes was expelled the house;

and though he retired to France, his trial was brought on in his absence, when he was found guilty of republishing the libel, and was consequently outlawed. Four years afterwards he returned to England, his outlawry was reversed, and he was sentenced to two years imprisonment; during which he was elected an alderman of London, and knight of the shire for Middlesex.

In the year 1780, from a cause apparently harmless, a petition to parliament from the Protestant Association, arose an insurrection, composed chiefly of the lowest of the people, which for a week bore the most alarming appearance; the prisons of Newgate, the King's Bench, and the Fleet were burnt and the prisoners set at liberty, and most of them joined the insurgents. The Popish chapels, and a great number of private houses of Catholics, were set on fire; and thirty six fires were seen blazing at one time in various parts of the metropolis. Military interference became absolutely necessary, when many of the rioters were killed; 135 were brought to trial, of whom 59 were convicted, and upwards of 20 of the most active were executed in various parts of the town, but immediately contiguous to the scenes of their respective depredations.

During the year 1792, and the two following years, the metropolis was greatly agitated by political contention; many associations were formed for the purpose of obtaining a more pure and equal representation of the people. The two principal of these associations, viz. the Friends of the People, and the Corresponding Society, held their meetings in London. Their avowed object was parliamentary reform; but they were stigmatized by their enemies with the appellations of Republicans and Levellers. Some of the most active and powerful leaders of these associations were at length arrested, and tried for high treason, but after a long investigation all were acquitted. Other persons, among whom was Thomas Paine, were prosecuted for sedition, and some were imprisoned. Paine was pronounced guilty of writing and publishing the second part of the Rights of Man, which was declared seditious, and the author having left the kingdom, was outlawed. The numerous clubs, debating societies, and political associations formed in the metropolis soon after the revolution in France, and during the early stages of the war against that country, constitute a prominent epoch in the history of the metropolis. The country was hurried on to the very brink of revolution; but this great crisis was prevented by the vigilant, powerful, and determined conduct of the Pitt administration. An Alien act was passed in 1793, the Habeas Corpus act was suspended in the next year; and various arbitrary and oppressive measures were adopted by the ministry to preserve public tranquillity, but at the same time abridge the rights of the British subjects.

The year 1797 was distinguished by the stoppage of bank payments in specie, as the government had employed nearly all the current coin in remittances to the emperor of Germany and to other foreign powers. An act of parliament was now passed to allow the bank to issue notes under five pounds. At the commencement of 1798 a numerous meeting of the bankers, merchants, and traders of London, was held in the Royal Exchange for the purpose of raising a voluntary subscription for the public service. In the course of four days the common council alone subscribed 10,000*l.*, 200,000*l.* was subscribed by the bank, considerable sums were given by other public companies, and 20,000*l.* was advanced by his majesty. The minister estimated this subscription at one million and a half, but the total amount was more than two millions of money. Continued threats of invasion from France induced the minister to adopt some new mode of defence; and several armed associations were

formed by different parishes and companies in the metropolis. On the 4th of June, 1799, all these volunteers were assembled in Hyde Park, and reviewed by his majesty, the princes, &c. The total number under arms was 8089, of which 1008 were cavalry. On the 21st of the same month, a still greater number of volunteers was dispersed through the streets, squares, and suburbs of the metropolis, to be inspected again by the king, and a numerous retinue of princes, dukes, &c. It is stated, that 12,208 volunteers were then drawn out under arms. A similar review of the volunteers to the former, took place on the 4th of June 1800. On the ratification of preliminaries of peace in October, 1801, the metropolis was brilliantly illuminated, and all classes of people testified great joy at the event. The definitive treaty was signed on the 27th of the following month, and the illuminations throughout London were now singularly splendid and general. A war again broke out, and an act of parliament was passed to enable his majesty to arm the people *en masse*. Other acts for increasing the military force of the country were also passed. The cities of London and Westminster, and parishes immediately adjacent, raised a volunteer force amounting to 27,077 men. A patriotic fund was established in London in July 1803, and before the end of August more than 152,000*l.* were subscribed; towards which the city, in its corporate capacity, gave 2500*l.* The successive deaths of lord Nelson, Mr. Pitt, and Mr. Fox, produced great sensation in the metropolis, and many changes in the legislative officers. Covent Garden theatre and several contiguous houses were consumed by fire in September 1808; another fire in January 1809, destroyed part of the king's palace at St. James's, and a third fire, in February of the same year, consumed the whole of Drury-lane theatre. The October of 1809 is memorable in the annals of London, for the circumstance of his majesty's entrance into the fiftieth year of his reign, and the loyal rejoicings, or public manifestations of loyalty that were displayed on the occasion. The memorable and unpropitious expedition to Walcheren, the theatrical riots at Covent Garden theatre, the investigation, before the house of commons, relating to the duke of York and a noted prostitute of the name of Clarke, the arrest and imprisonment of sir Francis Burdett, a member of the house of commons, are all memorable events in the local history of London, and are entitled to particular narration and exposition in a publication devoted to the topography of the metropolis. In Brayley's Survey, already referred to, these subjects are particularized and elucidated. It is conjectured that within the last forty years, 40,000 new houses at least have been erected in London and its connected environs, and that these afford habitation for nearly 200,000 new inhabitants. In July, 1794, a fire broke out in Radcliffe highway, and consumed 630 houses, with much other property. Many of the inhabitants fixed tents in the open fields, where they lived for several weeks till new houses were erected.

History of the Commerce of London.—

"Then COMMERCE brought into the public walk
The busy Merchant; the big Warehouse built;
Rais'd the strong Crane; and choak'd up the loaded Street
With foreign Plenty; and thy Stream, O Thames,
Large, gentle, deep, majestic king of floods!
Chose for his grand resort." Thomson.

London is universally acknowledged to be the first commercial, as well as the first manufacturing city in the world. Considering, therefore, the intimate connection that subsists between its trading prosperity and the general interests of the empire; the subject of this section cannot fail to be

highly interesting and important. To trace the steps by which London has risen to its present opulence and grandeur, is in fact to develop the sources of that distinguished rank which England now holds among the nations of the earth.

London was, doubtless, a place of considerable trade at a very early period. Tacitus speaks of it as the *nobile emporium* of his time; the great resort of merchants, and though not a colony, famous for its commercial intercourse. After this, little is known of it, in respect to trade, until the close of the second century of the Christian era, when it is again mentioned as having become "a great and wealthy city." In the year 359, it is said of England, that its "commerce was so extended, that 800 vessels were employed in the port of London for exportation of corn only." Three centuries afterwards Bede styles it "an emporium for many nations repairing to it by land and sea." Fitz-Stephen, who lived in the reign of Henry II. says, that "no city in the world exports its merchandize to such a distance as London;" but does not inform us what goods were exported, or to what countries they were carried. Among the imports, however, he enumerates gold, spices, and frankincense from Arabia; precious stones from India; and palm-oil from Bagdad. But it seems more reasonable to suppose these were obtained through the medium of the trading cities of Italy, than by direct commerce to the respective places. William of Malmesbury, who likewise lived about this period, calls "London a noble city, renowned for the opulence of its citizens," and "filled with merchandize brought by the merchants of all countries." The same author adds, "that in case of scarcity of corn in other parts of England, it is a granary, where it may be bought cheaper than any where else." Thus it will be perceived, that even in the infancy of European commerce, and at a time when ignorance and barbarism clouded almost every portion of the world, this city had made no inconsiderable progress towards its present celebrity and importance.

In the year 1220, the merchants of Cologne, in Germany, probably in consequence of an invitation from king John in 1203, established a hall or factory in London, which shortly after became the general factory of all the German merchants resident in the city. Not long subsequent to this period, *viz.* in 1245, sea coal "carbone maris," is mentioned among the articles of inquisition into trespasses committed in the king's forests. Hence it may reasonably be inferred, that coal was not only known and wrought before this time, but actually formed a part of the imports of London. Sea-coal lane, in this city, was certainly so named as early as the year 1253, and according to Stow, received this appellation from lime being burnt there with sea-coal.

The close of the thirteenth century appears to have been a remarkable era in the commercial history of London. In 1296, the company of merchant-adventurers was first incorporated by Edward I. The Hanseards, or Hanse merchants, also received considerable privileges about the same time. In the year 1498, when all direct commerce with the Netherlands was suspended, this body obtained very great advantages over the merchant adventurers by importation of vast quantities of those articles, through the medium of the Hanse towns, which before had come directly from the Netherlands, where the trade of the latter company had been chiefly established. In consequence of these circumstances, the warehouses of the merchants were attacked and rifled by the mob; but the offenders were soon suppressed, and many of them punished.

In the year 1504, all the ancient privileges of the Hanse, or as they were likewise called, Steel-yard merchants, were

confirmed to them by statute, and all the previous acts which had been made in derogation of them were annulled. A similar charter was also obtained by the English merchants "trading in woollen cloths of all kinds to the Netherlands," in which they are for the first time styled the "Fellowship of merchant-adventurers of England." This act strictly prohibited the Steel-yard association from interfering with their trade, by carrying cloths to any of their settlements in the Low Countries. Notwithstanding these unfavourable clauses, however, the Hanse-merchants seem to have engrossed the chief trade of the city. Grievous accusations were consequently made against them, for their proceedings were considered as tending to ruin the commerce of the native English. The city of London at length instituted an action, in the Star-chamber, against them, the object of which was to deprive them of their privileges as a body. Accordingly, in the year 1597, a decree was obtained, annulling their association, and ordering them, under severe penalties, to quit the kingdom. See *HANSE TOWNS*.

But to return: it may be proper to remark, that during the contentions between the houses of York and Lancaster, the commerce of London was very considerably retarded. In the reign of Henry VII. it again began to make rapid progress. Still, however, if credit is to be given to Wheeler's "Treatise on Commerce," published in 1601, the trade of this city must have been very low indeed, even as late as the year 1539; for that author expressly avers, that sixty years before he wrote, there were not above four merchant vessels exceeding 120 tons burthen in the river Thames. Nor would it appear that they had increased much in the next reign, if we are to believe the report of a London merchant, who, in a letter to sir William Cecil says, that there is not a city in Europe "having the occupying that London hath, so slenderly provided with ships."

Notwithstanding these complaints, however, it is undoubtedly a fact, that a spirit of enterprise was very general among the merchants about this period. For, in 1553, we find a great geographical and mercantile discovery made by a company, consisting of 240 shareholders, instituted for the purpose of prosecuting discoveries under the direction of Sebastian Cabot, a merchant of Bristol. (See *CABOT, SEBASTIAN*.) This association having fitted out three ships, one of them accidentally fell into the bay of St. Nicholas, in the White seas, and landing at Archangel, obtained from the czar of Russia peculiar privileges of trade with the subjects of his dominions. Within a few years after, the London merchants had also factors settled at the Canaries. The Russia or Muscovy merchants were incorporated in the reign of Philip and Mary, and had their charter subsequently confirmed by Elizabeth, in her eighth year. This princess, likewise, obtained an exclusive grant to the English of the whole foreign commerce of that extensive empire, which they continued to enjoy for a considerable period. About this time the civil dissensions in Flanders began, upon which a vast number of families from the Netherlands flocked to London, and brought over with them their trade and riches. This great addition to the population of the city, and the consequent increase of its commerce soon after, led to the erection of the Royal Exchange, by the celebrated sir Thomas Gresham, in the years 1566 and 1567. (See *ROYAL EXCHANGE*.) Previous to this the merchants were accustomed to meet twice every day in Lombard-street, without any other refuge from the severities of the weather but what the neighbouring shops might occasionally afford. In 1579, the Levant, or Turkey Company, was established, as was also the Eastland Company; both of which still exist, but the former only retains any degree of importance. On the

31st of December, 1600, the queen granted the first patent to the East India Company. Their stock then amounted to 72,000*l.* and with this sum the company was enabled to fit out four ships under the command of James Lancaster. The adventure proving successful, the company continued its exertions, and hence has arisen the most splendid and powerful mercantile association that probably ever existed in the world. (See COMPANY, *East India*.) Assurance and insurance companies were now established in London. An act was passed in 1601 for regulating the business of assurance, and a standing commission of merchants appointed to meet weekly "at the office of insurance on the west side of the Royal Exchange." (See INSURANCE Companies.) The company of Spanish merchants were likewise among the number of those incorporated by Elizabeth, so that the reign of that princess may be justly said to form a grand era in the commercial history of this metropolis.

In the reign of James I. the progress of the foreign trade was rapidly increased. Tobacco, which had first been introduced in 1565, now became a considerable article of import. (See TOBACCO.) The tonnage and number of the shipping in the port of London were greatly augmented about this time. Many of the patents granted by Elizabeth were annulled, and the trade thrown open. Howe, speaking of the foreign commerce of this city in the year 1614, says, "London, at this day, is one of the best governed, most richest, and flourishing cities in Europe; plentifully abounding in free trade and commerce with all nations; richly stored with gold, silver, pearl, spice, pepper, and many other *strange* commodities from both Indies; oyles from Candy, Cyprus, and other places under the Turk's dominion; strong wines, sweet fruits, sugar, and spice, from Grecia, Venice, Spayne, Barbaria, the islands and other places lately discovered and known; drugs from Egypt, Arabia, India, and divers other places; silks from Persia, Spayne, China, Italy, &c.; fine linen from Germany, Flanders, Holland, Artois, and Hanault; wax, flax, pitch, tarre, mastes, cables, and honey, from Denmark, Poland, Swethland, Russia, and other northern countries; and the superfluity in abundance of French and Rhenish wines, the immeasurable and incomparable increase of all which coming into this city, and the encrease of houses and inhabitants within the terme and compasse of fifty years, is such and so great, as were there not now two-thirds of the people yet living, having been eye-witnesses of the premises and bookes of the custom-house, which remain extant, the truth and difference of all things afore-mentioned were not to be justified and believed." Howe's edition of Stow's Annals of England, p. 868.

Among the circumstances which occasioned the vast increase of trade during this reign, may be reckoned the colonization of America and the West India islands. The new discoveries, likewise, which were every day made in different quarters of the world, no doubt had a powerful effect in stimulating numbers of speculating persons to commercial exertion and adventure.

During the peaceful years of Charles I. the commerce of this metropolis still continued to make rapid progress; and though the civil wars, for a time, had a very contrary operation, yet in the end they certainly proved beneficial. The energies of the mind were more awakened; the habits of thinking and modes of action, which then became general, taught man to feel his dignity as an individual; the different ranks of society were more closely drawn together; the exertions of industry were better directed; and the means of acquiring wealth greatly augmented. The injurious tendency of monopolies was eminently counteracted; for,

though never abolished by any direct statute, men, regardless of the prerogative whence they were derived, gradually invaded the privileges they conferred, and commerce was increased by the increase of liberty.

The augmented commerce of the port of London, in this reign, may in some measure be estimated by the quota of ship-money, which Charles I. imposed on the city in 1634. By one writ, the citizens were ordered to fit out and equip, at their own charge, for 26 weeks, one ship of 900 tons and 930 men, one of 800 tons and 260 men, four of 500 tons each and 200 men, and one of 300 tons and 150 men. Next year they were commanded to provide two ships of 800 tons and 320 men each. About this time, or at least very shortly before, prices-current were first printed. In 1635, an order was issued by the king in council to the "post-master of England for foreign parts," requiring him to open a regular communication, by running post between the metropolis and Edinburgh, Ireland, and a variety of other places.

Previous to the year 1640, it was usual for the merchants to deposit their cash in the Tower mint; but this deposit now lost all its credit by the ill-advised measure of a forced loan, which the king thought proper to make. The merchants, in consequence, found themselves obliged to trust their money to their apprentices and clerks. The circumstances of the times and opportunity holding forth great inducements to frauds, many masters lost at once both their servants and their money. Some remedy became necessary; and the merchants now began to lodge cash in the hands of the goldsmiths, whom they also commissioned to receive and to pay for them. Thus originated the practice of banking: for the goldsmiths, soon perceiving the advantages that might be derived from disposable capital, began to allow a regular interest for all sums committed to their care; and, at the same time, they commenced the discounting of merchants' bills at a yet superior interest than what they paid. (See BANK and BANKING.) In 1651 the celebrated navigation act was passed, the wise provisions of which have no doubt contributed much to promote our naval and commercial greatness. This same year, coffee was introduced into London by a Turkey merchant named Edwards. (See COFFEE.) The sugar trade was now likewise established; and upwards of 20,000 cloths were sent annually to Turkey, in return for the commodities of that country.

The plague, which made such dreadful havoc among the citizens in 1665, almost wholly suspended the commerce of London; inasmuch that scarcely a single foreign vessel entered the port for the space of three years. The great fire, which happened in 1666, likewise occasioned incalculable loss to numbers of the most opulent merchants in the city. Notwithstanding these disastrous events, however, the spirit of the survivors, so far from sinking, was roused to uncommon exertions. In the course of a few years, the city rose from its ashes with greater magnificence and splendour. India muslins were first worn in 1670, and soon became prevalent. In this year also was the Hudson's Bay Company established, with very extensive powers. The Greenland Fishing Company was incorporated in the year 1693; and the institution of the Bank of England rendered the succeeding one justly memorable in the commercial annals of London. See COMPANY.

The commerce to the East Indies having become vastly enlarged, and many disputes arising relative to exclusive trade, a new joint stock company was incorporated in London, in the year 1698, by the name of "The English Company trading to the East Indies." The existence of two rival companies having the same privileges, however,

soon gave birth to numerous absurdities and contradictory questions of right. These circumstances, and some others which it is unnecessary to detail in this place, eventually produced the consolidation of both into one, in the first and seventh years of queen Anne, by the title of "The United Company of Merchants trading to the East Indies." See COMPANIES, *English*, the *East India*, vol. ix. for a full account of this establishment.

The number of vessels belonging to the port of London, as appears from returns made to circular letters from the commissioners of the customs, amounted, in 1701, to 560; carrying 84,882 tons and 10,065 men. In 1710 the customs of this city are stated at 1,268,095*l.*, and those of all the out-ports only at 346,081*l.*, which is more than three and a half to one. The following year beheld the incorporation of the South Sea Company, afterwards so baneful in its effects to numerous individuals, and so generally hurtful to the commercial enterprise of the country at large. The Royal Exchange Assurance and the London Assurance Companies were chartered about the same time.

During the reign of George I. the trade of London made very little, if any, progress. The failure of the South Sea scheme, the rebellion in Scotland, and the Spanish war, were the combined causes which operated to produce its retardation. In the year 1732, however, commerce began again to revive; but its advances continued comparatively slow, till the peace of Aix-la-Chapelle in 1748, after which it extended with uncommon rapidity. The next considerable check it sustained was the result of the American war. No sooner, however, was peace signed than it proceeded with renewed vigour. The grievous consequences which many persons apprehended to our trade, from the declaration of the independence of the United States, were only imaginary. For, even so soon after that event as the year 1784, the value of exports to America only had increased to 3,397,500*l.*, somewhat more than 332,000*l.* above the greatest amount in any one year before the war. The net sum of duties levied in the port of London, and paid into the exchequer this year, arose to the vast sum of 4,472,091*l.* 13*s.* 3*d.* From this period to 1793, when the French revolution began, the commerce of London continued uniformly increasing. In that year, however, the value of exports was upwards of two millions less than in the preceding year; though the imports scarcely suffered any diminution. Numerous bankruptcies consequently took place; but the timely interference of the legislature, and the voting of exchequer bills to the amount of 5,000,000*l.* for the use of such persons as could give sufficient security, soon checked the growing distress.

In the course of the three succeeding years, the appearance of things was entirely altered. In 1796 the exports of London amounted in value to 18,410,499*l.* 17*s.* 9*d.*, and the imports to 14,719,466*l.* 15*s.* 7*d.* The number of British ships that entered the port amounted to 2007, carrying 436,843 tons; and 2169 foreign vessels, carrying 287,142 tons. The total entering coastwise was 11,176, including repeated voyages, which made a tonnage of 1,059,915. The following year, some alarm was spread among the merchants by the stoppage of the bank payments *in specie*; but, through the intervention of parliament, confidence was soon restored. The net amount of the customs was 3,950,608*l.* In 1798 the importations of sugars and rum far exceeded those of any preceding year, as did likewise the revenue of the customs, which amounted to the sum of 5,321,187*l.* 7*s.* 3*d.* In 1799 it had increased to 7,226,353*l.* 0*s.* 1*d.*, West India $4\frac{1}{2}$ per cent. duty included; but next year fell to 6,468,655*l.* 13*s.* 7*d.* The official

value of the imports, in 1800, was 18,843,172*l.* 2*s.* 10*d.*; and of the exports, 25,428,922*l.* 16*s.* 7*d.* Their *real* value amounted in all to 68,000,000*l.*, nearly two-thirds of the value of the whole trade of the kingdom. The number of vessels belonging to the port in that year appeared, from official documents laid before parliament, to be 2666, carrying 568,262 tons, and 41,402 men. Comparing this number with the number returned in the beginning of the last century, the increase will be seen to be astonishing. On the quantity of tonnage, it is nearly in the proportion of six to one; and on the amount of men and ships, as upwards of four to one. The East India Company's ships alone carry more burthen, by 21,166 tons, than all the vessels of London did a hundred years ago. The average number of ships in the Thames and docks is 1100, together with 3000 barges employed in lading and unlading them, 2288 small craft engaged in the inland trade, and 3000 wherries for the accommodation of passengers; 12,000 revenue officers are constantly on duty in different parts of the river; 4000 labourers are employed in lading and unlading, and 8000 watermen navigate the wherries and craft. See DOCKS and COMPANIES.

The *Port of London*, as actually occupied by shipping, extends from London bridge to Deptford, being a distance of nearly four miles, and from four to five hundred yards in average breadth. It may be described as consisting of four divisions, called the Upper, Middle, and Lower Pools, and the space between Limehouse and Deptford: the Upper Pool extends from London bridge to Union Hole, about 1600 yards; the Middle Pool, from thence to Wapping New Stairs, 700 yards; the Lower Pool from the latter place to Horse-ferry Tier, near Limehouse, 1800 yards; and the space below to Deptford about 2700 yards. When the house of commons commenced an investigation respecting the port of London, the land accommodations were found to consist of only the legal quays and the sufferance wharfs. The former were appointed in the year 1558, under a commission from the court of exchequer, authorized by an act of the first year of Elizabeth, for the exclusive landing of goods, subject to duty: they occupy the north bank of the river Thames, with some interruptions, from London bridge to the western extremity of Tower ditch; the whole frontage measuring about 1464 feet. Till of late years these quays constituted the whole legal accommodation for the prodigious shipping trade of London; though from the increased size and tonnage of merchant vessels, &c. the depth of the river in this part was found too shallow to admit of that speedy clearance which the trading and mercantile interests require. The commissioners of the customs, therefore, occasionally permitted the use of other landing places, which were thence called sufferance wharfs, and of which five were situated on the north side of the river, between the Tower and Hermitage Dock, and eighteen on the opposite side: the whole having a frontage of 3676 feet. Notwithstanding these additional conveniences, the whole number of quays was still very far from possessing sufficient accommodation for the increased trade; and more especially in times of war, when large fleets of merchantmen arrive at once. The numerous evils arising from this want of a sufficient space for shipping and landing goods, and among which, the monopoly thrown into the hands of the few legal quays was not the least, were for many years subjects of vexation and complaint. So long ago as 1674, the merchants of London petitioned the house of commons for redress against a combination, which the whole body of wharfingers had entered into; and in the year 1711, when the tonnage of the vessels belonging to London did not amount to one-third

part of what it does now, the commissioners of the customs recommended to government to make a legal quay at Bridge yard, on the south side of the river; but it was never executed. About the year 1762, the court of exchequer directed a part of the Tower wharf to be converted into a legal quay; but this plan was relinquished. The construction of Wet docks had been recommended as the best expedient for obviating the vast loss and embarrassment arising from the encumbered state of the quays and wharfs, and from the immense crowding of the vessels on the river; and through the various schemes which were about this time offered for the purpose, &c. the house of commons was induced to appoint a committee; the business of which has been to inquire into the best mode of improving the port, and render it completely adequate to the present and probable commerce of London. The most skilful engineers and surveyors have been employed; whose reports, plans, &c. with the opinions and statements of various merchants and other persons, have been printed by order of the house of commons. These reports constitute several volumes in folio; and are peculiarly interesting and curious. Sir Frederic Eden published a pamphlet on the same subject, entitled "Porto-Bello, or a plan for the improvement of the port and city of London; illustrated by plates," 8vo. 1798. For a particular account of the various branches of commerce, commercial companies, and other objects connected with the same, the reader is referred to the words **DOCKS, COMPANIES, EAST INDIA Trade, WEST INDIA Trade.**

Custom House.—On the north bank of the Thames, west of the Tower, is a large building, appropriated to such officers, clerks, tide-waiters, &c. as are immediately concerned in receiving the king's duties on the exports and imports of commerce. The present building was erected in 1718, on the site of another which had been destroyed by fire. It is 260 feet in front; and when erected was deemed amply sufficient for its destination. It has proved, however, very inadequate to the increased customs and business of the port; and to the vast commerce of London. After various surveys and reports made on the subject, it has been recently determined by the commissioners of the customs, that a new custom-house shall be erected, upon such a scale, and provided with such numerous and various accommodations, as to meet the exigencies and demands of government. Mr. David Laing, architect to the customs, having furnished designs for a new edifice, and the same being approved, it is intended to proceed with the building immediately. The site is from the western side of the present edifice to Billingsgate quay; and its whole extent will constitute a range of 480 by 96 feet. In the centre is to be the long room, of 190 feet by 67. The whole building will accommodate 650 officers and clerks, the number employed here; also 1050 tide-waiters, and other inferior servants. The lower floor is to consist of bondage vaults, over which are to be numerous apartments for officers and offices; and above these are to be several others, with the long room already noticed. The water front is to be of stone, with Ionic columns at each wing, and the centre will be crowned with a large dome over the long room, with sky-lights and ventilators. It is but justice to say that the designs are creditable to the taste and science of the architect. The quay in front of the building is to be enlarged by filling up a part of the river. A new wall and quay are to be formed from the Tower to Billingsgate wharf, and numerous improvements will be made in the contiguous streets and lanes. The river, at this place, is about 20 feet deep at high water mark. The business of the customs is managed by nine commissioners, whose jurisdiction extends over all the ports of England.

Manufactures of London.—London has long been celebrated for its manufactures as well as for its commerce. In the year 1327 the Skinners were a very numerous and rich class of citizens, manufacturing "sables, lucerns, and other rich furs." Cloth-workers of different kinds were also noted for the excellence of their goods. In 1556 a manufactory for the finer sort of glasses was established in Crutched Friars, and flint glass, not exceeded by that of Venice, was at the same time made at the Savoy. About five years subsequent the manufacture of knit stockings was introduced by one William Rider, an apprentice in London, who happening to see a pair from Mantua at the house of an Italian, made another exactly similar to them, which he presented to William earl of Pembroke. (See **HOSIERY AND STOCKINGS.**) A manufacture of knives was shortly after begun by Thomas Matthews of Fleet-street, and this has ever since been a flourishing trade. Silk stockings were first made in England in the reign of queen Elizabeth. In the fourth year of that princess, "John Rose, dwelling in Bridewell, devised and made an instrument with wyer stringes, called the Bandora, and he left a son far excelling him in making bandoras, viol de gamboles, and other instruments." Coaches were introduced in 1564, and in less than 20 years became an article of great manufacture. The following year the manufacture of pins was established, and shortly after that of needles. The making of "earthen furnaces, earthen fire-pots, and earthen ovens, transportable," began about the tenth year of Elizabeth, one Richard Dyer, an Englishman, having brought the art from Spain. Women's masks, busks, muffs, fans, bodkins, and periwigs were introduced and made in London shortly after the massacre at Paris in the year 1572, and in 1577 pocket watches were brought from Nuremberg in Germany, and the manufacture of them almost immediately commenced. In the reign of Charles I. saltpetre was made in such quantity, as not only to supply all England, but the greater part of the continent. The manufactures of silk had likewise become extremely prevalent, as well as the manufacture of various silver articles. The printing of calicoes commenced here in 1676, and about the same time the weavers' loom was introduced from Holland. The revocation of the edict of Nantes in 1685, having driven many industrious Frenchmen from their native land, a considerable number came over to England and settled in Spitalfields. By them several of our manufactures, but particularly that of silk, were greatly improved, and many others introduced. Since then the productions of London have greatly increased both in extent and value. They now consist chiefly of fine goods, and articles of elegant use, brought to the greatest perfection, such as cutlery, jewellery, articles of gold and silver, japan ware, cut glass, books, cabinet work, and gentlemen's carriages; together with such particular articles as require a metropolis, or a port, or great mart for their consumption, export, or sale; viz. porter, English wines, vinegar, refined sugar, soap, &c. The silk manufactories of Spitalfields, Shoreditch, and Bethnal-green parishes, alone employ upwards of 7000 persons. In Clerkenwell a like number are engaged in the different branches of watch-making. Coach builders and harness makers are very numerous, and have brought their respective works to a higher degree of perfection and elegance than any in the world. Intimately connected with this subject is the

Trade of London, which is vast, various, and of extensive effect. It may be divided into the wholesale and retail business; for these are different, and under different systems of management. The great number and variety of shops that are dispersed over the metropolis, the diversity, richness, and multitude of articles displayed for sale, and the great con-

course of persons immediately and collaterally dependent on, and intimately connected with the same, are calculated to excite the astonishment of foreigners, and of persons who have not made inquiries into the subject. The wholesale trade is mostly carried on in the city, and in the vicinity of the river, where large warehouses and counting-houses are established. The retail trade is dispersed through all the public streets: where spacious and handsome shops are opened for the display of all the necessaries, as well as all the luxuries of life. The shop-keepers of London are mostly an active, industrious, and respectable class of society: many of them are wealthy, and frequently retire from business in advanced age, with competence, or fortunes. Among the most modern shop establishments upon a large scale, are those appropriated to books and prints. Within the last 50 years, these have been prodigiously increased: and it would greatly astonish Addison, Johnson, or Sir Joshua Reynolds, could they revisit London in 1812, and take a review of the change that has been produced since the time they lived, in the quantity and quality of literary productions, and in works of art. The regular, continued and perpetual intercourse that subsists between London and all parts of the kingdom, by coaches, waggons, barges, &c. constitutes another and strongly marked feature.

Provisions, &c. used in London.—An immense population will require a large and systematic supply of provisions; and in this respect, no city in the world can be better accommodated; laws, custom, and open competition are all conducive to public advantage.

Animal Food. The number of oxen annually consumed in London is estimated at 110,000; of sheep, 770,000; of lambs, 250,000; of calves, 250,000; of hogs and pigs, 200,000; besides animals of other kinds. In speaking of the consumption of animal food in London, it is not sufficient to notice merely the number of animals brought to market; for their size and fine condition should also be considered in forming a proper criterion. The increased consumption of the metropolis, from its accumulating population, may be estimated from the following average of the number sold annually in Smithfield.

	Oxen.	Sheep.
From 1750 to 1758	75,331	623,091
1759 — 1767	83,432	615,328
1768 — 1776	89,362	627,805
1777 — 1785	99,285	687,588
1786 — 1794	108,075	707,456

It is not only in number but in weight that there has been an astonishing increase; this has arisen from the improvements in breeding that have taken place in the course of the last century. About the year 1700, the average weight of an ox, killed for the London market, was 370lbs.; of a calf, 50lbs.; of a sheep, 28lbs.; of a lamb, 18lbs.; whereas the average weight at present is, of oxen, 800lbs. each; of calves, 140lbs. each; of sheep, 80lbs. each; and of lambs, 50lbs. each. The total value of butchers' meat sold in Smithfield is calculated to amount to 7,000,000*l.* *per annum.*

Milk.—The quantity of this article consumed in London surprises foreigners; and yet few persons have even a suspicion of the amount, which is not less than 6,980,000 gallons annually. The number of cows kept for this supply is said to be 8500; the sum paid by the retailers of milk to the cow-keepers is stated at 317,400*l.* annually, on which the retailers lay an advance of *cent. per cent.*, making the cost to the inhabitants 634,000*l.* Not content with

this profit, the retailers add water to the milk, to the extent, on an average, of a sixth part. Though the cow-keepers do not themselves adulterate the milk, (it being the custom for the retailer to contract for the milk of a certain number of cows, to be milked by his own people,) yet they are not wholly to be acquitted of the guilt; for in many of the milk-rooms where the milk is measured to the retailer, pumps are erected for the express purpose of furnishing water for the adulteration, which is openly performed in the presence of any person who happens to be on the spot. See MILK.

Vegetables and Fruit.—There are at least 10,000 acres of ground near the metropolis, cultivated wholly for vegetables, and about 3000 acres for fruit. The sum paid at market annually is about 645,000*l.* for vegetables, and about 400,000*l.* for fruit; independently of the advance of the retailers, which, on an average, is more than 200*l. per cent.*, making the entire cost for the London supply upwards of 3,000,000*l.*

Wheat, coals, &c.—The annual consumption of wheat in London is, at least, 900,000 quarters, each containing eight Winchester bushels; of coals 800,000 chaldron, 36 bushels, or a ton and half to each chaldron; of ale and porter 2,000,000 barrels, of 36 gallons each; spirituous liquors and compounds 11,146,782 gallons; wine 65,000 pipes; butter about 21,265,000lbs.; and cheese, 25,500,000. The quantity of porter brewed from July 5, 1809, to July 5, 1810, by two of the principal brewers, was, by Barclay, Perkins, and Co. 235,053 barrels, and by Meux, Reid, and Co. 211,009. (See PORTER.) The quantity of fish consumed in the metropolis is comparatively small, on account of the high price which it generally bears; and this appears to be the most striking defect in the supply of the capital, when it is considered that the rivers of the kingdom, and the seas which surround it, must afford such an amazing quantity. There are, on an average, annually brought to Billingsgate market 2500 cargoes of fish, of 40 tons each, and about 20,000 tons by land-carriage, in the whole 120,000 tons. The supply of poultry being inadequate to a general consumption, and the price consequently exorbitant, this article is confined to the tables of the wealthy, and the annual value does not exceed 60,000*l.* Game is not publicly sold, yet a considerable quantity, by presents, and even by clandestine sale, is consumed by the middling classes. Venison is sold, chiefly by pastry-cooks, at a moderate rate; but the chief consumption, which is considerable, is amongst the proprietors of deer parks.

Markets, &c.—London contains 15 flesh markets, one for live cattle, sheep, horses, &c. and 25 for corn, coals, hay, vegetables, &c. Of these the principal are, at Smithfield, for bullocks, sheep, horses, swine, hay, straw, &c.; Leaden-hall, for butchers' meat, wool, hides, &c.; Billingsgate, for fish; Covent garden and Fleet, for fruit and vegetables; Newgate, Newport, Carnaby, and Clare markets, for butchers' meat, &c.; the corn market in Mark-lane: in Thames street is a coal exchange. London has only one annual fair, which is held in Smithfield, and continues for three days. It is mostly devoted to objects of amusement, such as shows, exhibitions of beasts, birds, flights of hand, and the very lowest species of diversion. Hence it is mostly frequented by the lowest and most depraved classes of society. It is become more a place of riot and debauchery, than of public utility.

From what has been stated respecting the provisions annually consumed in London, we are naturally led to inquire into its population; an accurate knowledge of which forms

a foundation for much curious speculation. In the following table we are enabled to give the total number of persons at four different periods; but it may be necessary to premise, that the last is presumed to be the most correct census ever taken in London.

Population.—London is less populous, for its extent, than many other great cities. The streets are wider, and the inhabitants of every class, below the highest rank, enjoy more room for themselves and families than is usual for the same classes in foreign countries. Hence a given number of people is spread over a larger space in London than in foreign

cities. From the report on the population of Great Britain, published on the authority of an act passed 43 G. III. London, including the suburbs, appears to contain 837,906 settled inhabitants; but the great number of soldiers, mariners, provincial visitors, colonists, and foreigners, who are constantly in London, for purposes of pleasure and business, and the new inhabitants of 10,000 houses built within the last seven years, extends the total population to more than a million. As the increase or diminution of the population claims a distinct notice, the following table will shew its five divisions, at four different periods.

	In 1700.	1750.	1801.	1811.
1. City of London, within the walls - - - -	139,300	87,000	78,000	80,000
2. City of London, without the walls, including the Inns of Court -	169,000	156,000	155,000	168,000
3. City and Liberties of Westminster - - - -	130,000	152,000	165,000	180,000
4. Out-parishes within the Bills of Mortality - - - -	226,900	258,900	379,000	460,000
5. Parishes not within the Bills - - - -	9,150	22,350	123,000	135,000
Total population of the Metropolis -	674,350	675,250	900,000	1,023,000

Government of London.—In tracing the outline of the present government of this metropolis, it will be proper to divide it into three principal parts; viz. the city of London, with its dependencies; the city and liberties of Westminster; and the suburbs connected with the two, but out of the jurisdiction of both the cities.

The civil government of the city of London is vested, by charters and grants from the kings of England, in its own corporation or body of citizens. The city is divided into 26 principal districts, called wards; and the corporation consists of, 1, the lord mayor; 2, the aldermen; and 3, the common council. The lord mayor is chosen annually in the following manner: on the 29th of September, the livery, in Guildhall or common assembly, choose two aldermen, who are presented to the court of lord mayor and aldermen, by whom one of the aldermen so chosen, (generally the senior,) is declared lord mayor elect; and on the 9th of November he enters on his office. The aldermen are chosen for life by the free householders of the several wards, one for each ward; except Bridge-ward without, where the election is by the court of aldermen from among those who have passed the chair, commonly the senior: he is styled father of the city. The common council are chosen annually by the free householders in their several wards, the number for each ward being regulated by ancient custom; the body corporate having a power to extend the number. The common council are the representatives of the commons, and compose one of the parts of the city legislature, which nearly resembles that of the kingdom; for as the latter consists of king, lords, and commons, so this is composed of lord mayor, aldermen, and common councilmen; the principal difference is, that in the three estates of the kingdom each enjoys a separate negative, while in the city this right is denied to the lord mayor, and confined to the aldermen and common council. Before the year 1347, there were only two common-councilmen returned for each ward, which being thought insufficient to represent such a numerous body, it was at that time settled that each ward should choose a number, not more than twelve, or less than six, according to its dimensions; which has since been increased to the present number. The 26 wards are subdivided into 236 precincts, for each of which a representative is elected in the same manner as the aldermen; with this difference,

that as the lord mayor presides in the wardmote, and is judge of the poll at the election of an alderman, so each alderman, in his respective ward, presides at the election of common council men. The civil powers exercised by the corporation are very complete: the laws for the internal government of the city are wholly framed by its own legislature, called the court of common council, which consists of the lord mayor, aldermen, and representatives of the several wards, who assemble in Guildhall as often as the lord mayor thinks proper to convene them. They annually select six aldermen and twelve commoners for letting the city lands, and this committee generally meet at Guildhall on Wednesdays. They also appoint another committee of four aldermen and eight commoners for transacting the affairs of Gresham-college, who usually meet at Mercer's-hall, at the appointment of the lord mayor, who is always one of the number. The court of common council also, by virtue of a royal grant, annually choose a governor, deputy, and assistants, for the management of the city lands in Ireland. This court also dispose of the offices of town-clerk, common serjeant, judges of the sheriffs' court, common crier, coroner, bailiff of the borough of Southwark, and city garbler. The election of the recorder is vested in the court of aldermen only. The lord mayor is the chief magistrate of the city: and the aldermen are the principal magistrates in their several wards. The lord mayor, the recorder, the common serjeant, and the aldermen, are judges of oyer and terminer (that is, the king's judges to try capital offences and misdemeanors) for the city of London and county of Middlesex; and the aldermen are perpetual justices of the peace for the city. The two sheriffs, (who are strictly officers of the king, for many important purposes of his executive government,) are chosen annually by the livery of London, not only for the city, but for the county of Middlesex, the same persons being sheriffs for London, and jointly forming one sheriff for the county. (See Philips's Letter on the Office of Sheriff, 8vo. and SHERIFF.) The administration, in all its branches, within the jurisdiction of the corporation, in all cases embracing the city and the borough of Southwark, and in some cases extending beyond, is exercised by members of the corporation or its officers. The borough of Southwark was formerly independent of the city of London, and appears to have been governed by

a bailiff till the reign of Edward III., who granted the government of it for ever to the city. A part has been since incorporated with the city, under the appellation of Bridge Ward Without, and has its officers appointed by the court of common-council. The livery is a numerous, respectable, and important elective body; in which is vested the election of the lord mayor, sheriffs, chamberlain, members of parliament, bridge-masters, ale-conners, and auditors of the chamberlain's accounts. The lord mayor, aldermen, common-council, and livery of London, form together the most important popular assembly, the commons house of parliament excepted, in the kingdom. On occasions of the greatest moment, their decisions have inspired general fortitude; and the whole legislature, when under evil influence, has been struck with awe by the remonstrance of the city, and prudently listened to a warning so solemnly pronounced.

The military government of the city of London was considerably changed by an act of parliament passed in the year 1794; under which two regiments of militia are raised in the city; by ballot, amounting together to 2200 men. The officers are appointed by the commissioners of the king's lieutenancy for the city of London; and one regiment may, in certain cases, be placed by the king under any of his general officers, and marched to any place not exceeding twelve miles from the capital, or to the nearest encampment; the other, at all such times, to remain in the city. Regiments of associated volunteers are formed in the respective wards and parishes, for the internal defence and peace of the metropolis. A considerable force is also maintained by the Bank, India-house, Custom-house, and other public bodies, for their more immediate security. The Artillery company, which is principally composed of a voluntary enrolment of the younger citizens, affords an additional force of about six hundred men. (See ARTILLERY.) See also Highmore's History of the Artillery Company, 8vo.

The civil government of the suburbs is vested in the justices of the peace for the county. The county-hall for Middlesex is on Clerkenwell-green, where the quarter-sessions are held; and a great part of the civil government is exercised. In Bow-street, Covent-garden, is an office of police, under the direction of certain justices of Middlesex, who dedicate their time chiefly to that office, where are first examined the most serious cases of misdemeanor. The other public offices of police, where magistrates sit daily, are—the Mansion-house and Guildhall, within the city. In the suburbs—Bow-street; Queen-square, Westminster; Marlborough-street; Hatton-garden; Worship-street; Lambeth-street, Whitechapel; High-street, Shadwell; and Union-street, Southwark: at Wapping New-stairs is an office for enquiry into offences connected with the shipping and port of London.

The police of London is under the controul of the magistrates belonging to these offices; who are appointed and paid by the government. They are required to attend on duty every day, and their province is to hear and determine petty offences, and subjects of dispute between individuals. On many occasions they investigate felonies, and the higher classes of crimes, and commit the offenders to the proper prisons. Different acts of parliament have been passed on this subject, by which the duty and powers of the magistrates and subordinate officers are particularly defined. The police of the city of London is regulated by acts passed in 10 Geo. II. 11, 14, 33, and 34 Geo. III.: of Westminster and its liberties, by acts of 27 Eliz., 16 Cha. I., 29 and 31 Geo. II. 2, 3, 5, 11, and 19 Geo. III.: municipal regulations are also established in the borough of Southwark, by acts 28 Geo. II. and 6 and 14 Geo. III.

Under the foregoing acts, a nightly watch is appointed for the prevention of robberies, and the apprehension of offenders. To the city of London are attached 765 watchmen, and 38 patrols. The whole number of headles, patrols, and watchmen, who are every night on duty in and around the metropolis, is estimated at 2044. Watch-houses are placed at convenient distances in all parts, where parochial constables attend in rotation to keep order, receive offenders, and deliver them the next morning to the fitting magistrate. In the winter season, the roads adjacent to London are additionally guarded by horse-patrols; and on extraordinary occasions, the officers of the police are ordered out, or kept in readiness, to assist in the preservation of the public peace. The nightly watch is of peculiar utility in case of fire, as in every watch-house the names of the turncocks, and the places where engines are kept, are to be found. Besides parochial engines, many public bodies are provided with them, and the principal fire-offices have engines stationed in various districts, with active men and horses. By means of the fire-plugs, water is immediately supplied, and the general security is guaranteed by every effort of vigilance and activity.

Acts of Parliament relative to London and its Inhabitants.—The internal economy, government, police, and civil regulations of London, are entitled to particular and commendable notice; because these have tended to attract foreigners to settle here, and induced numerous families, both tradesmen and persons of fortune, to fix on this city as a desirable place of permanent residence. It will be found that many legislative acts have been passed, and are in force, to secure the safety and comfort, and administer to the luxuries of the inhabitants of this metropolis. Besides numerous local acts of parliament that apply to particular parishes and districts, the following have been passed expressly for the above purposes. It is thought advisable to specify these acts, and point out some of their items; because many local advantages and conveniences of London are to be referred to these legislative provisions.

By 3 Hen. VII. c. 9, citizens and freemen of London are authorised to carry their wares to any fair or market in the kingdom, in spite of any bye-law to the contrary. By 6 Geo. II. c. 22, the lord mayor and citizens were empowered to fill up part of Fleet Ditch, and the inheritance of the ground was vested in them. By 29 Geo. II. c. 40, the lord mayor and common-council were empowered to purchase and remove buildings, to improve, widen, and enlarge the passage over and through London-bridge.

Buildings.—In the year 1764, a very important act of parliament was passed, respecting all buildings which are hereafter to be erected within London, Westminster, the bills of mortality, and the parishes of Mary-le-bone, Paddington, Pancras, and Chelsea, whereby it is provided, that they shall be divided into seven rates, of which the external walls shall be of a thickness proportionate to their rates or sizes; those of first-rate buildings to be at the foundation $2\frac{1}{2}$ bricks, or 1 foot $9\frac{1}{2}$ inches thick, and decreasing upwards in a degree therein specified. Another act, of a more ample nature, was passed in 1774, respecting the buildings of London and its vicinage. By this it is required, that houses contiguous to other buildings shall have party-walls between them, which walls and all chimnies and chimney-shafts shall be of brick or stone, or both together. (See CHIMNEY.) Party-walls shall be 18 inches above the buildings adjoining, and those of first-rate buildings shall be at the foundation $3\frac{1}{2}$ bricks, or 2 feet $6\frac{1}{2}$ inches in thickness, decreasing upwards in a given proportion. No recesses to be made in party-walls (except for chimnies, fires, girders,

&c.) so as to reduce such wall under the thickness required. No timber to be in the party-walls (except bonds, templets, and chains, and the ends of girders, beams, &c.) and 8½ inches of solid brick-work to be between the ends and sides of every piece of timber, except opposite to other timbers, and then no part of such timber to approach nearer than four inches to the centre of the wall. Surveyors are to give information of irregular buildings, and the lord mayor and justices are to order the same to be demolished or amended, and 50s. penalty is chargeable on the workman. Fire-engines and ladders to be kept in known places in every parish; and parish officers shall place on the mains of water-works, stop-blocks, and fire-cocks, and shall mark the house near. In case of fire, the turncock whose water comes first shall be paid 10s. First engine 1l. 10s., the second 1l., the third 10s. Where officers pay rewards for fires in chimnies only, or beginning there, they are to be reimbursed by the occupier. Servants who through negligence set fire to any house, shall forfeit 100l. or be committed to hard labour for 18 months.

Butchers.—It is provided by an act of Hen. VII. c. 3, that butchers shall not kill beasts within the walls of London; but this act is either superseded or not put in force.

Cattle.—By 14 Geo. III. c. 87, and 21 Geo. III. c. 67. any peace officer may arrest persons who drive cattle through the streets of London in an improper or cruel manner. The party, if convicted, shall forfeit from 5s. to 20s. or be committed for one month. Persons not being drivers of cattle, who shall throw stones or set dogs at them, shall be subject to the same penalties.

Carts.—By 1 Geo. I. stat. 2. c. 57, no carman, drayman, waggoner, or other person shall, within the bills of mortality, ride on a cart, dray, or waggon, not having some person on foot to guide the same, on forfeiture of 10s. This penalty is extended to within ten miles of London, by 24 Geo. II. c. 43.

Coals.—By 47 Geo. III. sess. 2. c. 68, the coal exchange shall be a free open market on Monday, Wednesday, and Friday, from twelve o'clock till two, and coals are only to be sold in market hours, under a penalty of 100l.

Hackney Coaches.—The commissioners may licence 800 by act 9 Anne, 200 more by 11 Geo. III., and 100 more by 42 Geo. III.; total 1100. The rates of fares are fixed, and an office is appointed to determine on complaints, and are also cognizable by magistrates.

Paving, lighting, and cleansing.—Several acts were passed in the reign of Hen. VIII. for paving parts of the metropolis. The eastern suburbs were paved by act 13 Eliz. Various other acts were passed in subsequent reigns for paving the several parts which were added to the metropolis. The *new paving*, according to the present mode, commenced in 1763, under an act passed in the preceding year. Before this period the streets were extremely inconvenient to passengers, the stones (mostly Guernsey pebbles) being round, the kennels in the midst, and no level footway, as at present, for the pedestrians. The alterations first took place in Westminster, and the improvements progressively extended through most parts of the metropolis. At this period also took place the removal of the enormous signs which hung across the streets or over the footways, and, together with their posts and iron scroll works, impeded as well the circulation of the air as the progress of the passenger.

Lighting.—As early as the year 1416, the inhabitants of London were obliged to hang out lanterns on winter evenings. Among other improvements in the reign of queen Anne, was the introduction of globular glass lamps

with oil burners, instead of the lanterns with candles, and common lamps that had previously been in use. In 1736, an act of parliament was procured to regulate "the better enlightening the streets, &c." within the city. A committee appointed to carry this act into execution, reported that "the number of houses then inhabited and chargeable (*i. e.* such as were subject to poor-rates) was in all 14,014, of which 1287 were under the rent of 10l. *per annum*; 4741 of 10l. and under 20l.; 3045 between 20 and 30l.; 1839 between 30 and 40l.; and 3092 of 40l. and upwards. The number of lamps required was 4200, exclusive of such as were attached to public buildings. They were to be placed at the distance of 25 yards from each other in the principal streets, and 35 yards in the smaller streets and lanes. This was the commencement of the system of defraying the charges of lighting the metropolis by parochial assessments. Since this time various other acts of parliament have been obtained for different districts in the suburbs, and it is conjectured that more than 30,000 lamps are lit every night within the bills of mortality. From Lady-day to Michaelmas, a less number is used than during the other half of the year. In 1737, an act of parliament was passed for regulating and increasing the city watch, &c. Various acts have been passed for cleaning the streets, and preserving them from obstructions and nuisances of every description.

Sewers.—One of the most essential objects in a large city is good drainage; and in this respect London is well provided. Into the deep channel of the Thames, numerous large sewers communicate, and convey all the superfluous water, and vast quantities of filth from the houses. By acts of the legislature, a number of persons, styled commissioners of sewers, are empowered to make and repair sewers, and levy a tax on every housekeeper towards defraying the expences incurred by the same. An act of parliament was obtained as early as the reign of Henry VI. on this subject; and this has been amended and enlarged by subsequent acts, 6th Henry VIII. cap. 10; 23d Henry VIII. cap. 5; and 25th of same reign; afterwards in the 3d and 4th of Edward VI.; 1st of Mary; 13th of Elizabeth; 3d of James, and 7th of Anne. See SEWERS.

By an act of parliament passed in 1737, the number of playhouses was limited to three, and all dramatic pieces intended for the stage, were first to be subjected to the perusal and approbation of the lord chamberlain. See PLAYHOUSE.

The Charitable Institutions of London are numerous, of various descriptions, and of incalculable advantage. Whilst they administer comfort, health, education, and protection to the necessitous, they reflect much honour on the affluent, and on all the patrons. These consist of hospitals, dispensaries, alms-houses, charity schools, benefit societies, and other establishments. In a former part of this work, under the word HOSPITAL, will be found accounts of several, to which we shall add a few particulars. In the metropolis are 22 hospitals for sick, lame, and for pregnant women; 107 alms-houses for the maintenance of aged persons of both sexes; 18 institutions for the support of the indigent of various other descriptions; above 20 dispensaries for the gratuitous supply of medicine and medical aid to the poor; 45 free-schools with perpetual endowments, for educating and maintaining 3500 children; 17 other public schools for deserted and poor children; 237 parish schools, supported by voluntary contribution, in which about 9000 boys and girls are constantly clothed and educated; each parish has also a work-house for the maintenance of its own helpless poor. Exclusive of this ample list, the several livery companies of

the city of London distribute above 75,000*l.* annually in charities; and there is a multitude of institutions, of a less prominent nature than the foregoing, which make the total of charitable donations immense. The sums annually expended in the metropolis for charitable purposes, independently of the private relief given to individuals, have been estimated at 850,000*l.* The hospitals were chiefly founded by private munificence: some are endowed with perpetual revenues, and others supported by annual or occasional voluntary subscriptions. The alms-houses were built and endowed either by private persons or corporate bodies of tradesmen. Many of the free-schools owe their origin to the same sources. The magnitude of the buildings dedicated to public charities, and the large revenues attached to them, are highly deserving of commendation; and the general administration of these establishments confers a peculiar honour on the capital. The interior regulations of the hospitals well accord with the exterior magnitude: the medical assistance is the best the profession can supply; the attendance is ample; the rooms are generally very clean and wholesome; and the food is proper for the condition of the patients. The alms-houses, and other institutions for the support of the aged and indigent, exhibit not merely an appearance, but a real possession of competence and ease. From some of the free-schools, pupils have been sent to the universities as learned as from any of the most expensive seminaries: and all the scholars receive an education completely adapted to the stations for which they are designed. Among the free-schools may be particularly noted those of Westminster, Blue-coat or Christ's-hospital, St. Paul's, Merchant-taylors', Charter-house, and St. Martin's. For a very ample history and description of all the charitable institutions of London, the reader is referred to a volume published in 1810, entitled, "*Pietas Londiniensis; the History, Origin, and present State of the various public Charities in and near London,*" by A. Highmore, 12mo.

Institutions.—For the accommodation and convenience of the immense population of the metropolis, the following institutions have been formed for education, for promoting good morals, for advancing the useful and fine arts, and for charitable and humane purposes. For education (besides the various schools already mentioned) there are 16 inns of court and chancery for students in the law, &c. (see *COURT, Inns of*;) and five colleges, *viz.* Sion-college, at London-wall, for the improvement of the clergy; Gresham-college, for divinity, astronomy, and other sciences; the college of physicians, Warwick-lane, for professors in medicine; one for the study of civil law, Doctor's Commons; and the Herald's-college. (See *COLLEGE*.) The number of private schools, for all the various branches of male and female education, is estimated at 3730; including some for children who are deaf and dumb.

For promoting religion and good morals London contains the following societies: 1. For giving effect to the king's proclamation against vice and immorality, established in the year 1787, and for the suppression of vice in 1803: 2. For promoting Christian knowledge, founded in 1699: 3. For the propagation of the gospel in foreign parts, incorporated in 1701: 4. For promoting religious knowledge, by distributing books to the poor, instituted in 1750: 5. For promoting charity schools in Ireland: 6. For religious instruction to the negroes in the West Indies, incorporated in 1795; and African education society, instituted in 1800: 7. For preventing crimes, by prosecuting swindlers and cheats, 1767: 8. For the encouragement of servants, 1792: 9. For the relief of poor pious clergymen, 1788: 10. For giving bibles to soldiers and sailors, 1780: 11. For giving bibles, and otherwise furthering the purposes of Sunday schools,

1785: British and foreign bible society, 1804. To these may be added, Dr. Bray's charity for providing parochial libraries; and queen Anne's bounty for the augmentation of small livings of clergymen.

For the promotion of learning, and advancement of the useful and fine arts, are the following institutions: 1. The Royal society, incorporated for promoting useful knowledge, was instituted 1663: 2. Antiquarian society, Somerset-place, 1751: 3. Society, or trustees of the British Museum, 1753: 4. Royal Academy of Arts, Somerset-place, 1768: 5. Society for encouragement of learning, Crane-court, Fleet-street: 6. Society for encouragement of arts, manufactures, and commerce, in the Adelphi-buildings: 7. Medical society of London, Bolt-court, Fleet-street, 1773: 8. Society for the improvement of naval architecture: 9. Veterinary college, St. Pancras: 10. Royal institution for applying the arts to the common purposes of life, 1799: 11. The London institution, in the city, 1805: 12. The Surrey institution near Blackfriars-bridge, 1808: 13. The Russel institution, Cornhill-street, Russel-square, 1808: 14. The Literary fund, established in 1793, &c.

Among the institutions for charitable and humane purposes, the following may be enumerated: 1. The humane society for the recovery of drowned and suffocated persons: 2. Society for the relief of merchants' seamen: 3. Several societies for support of widows in general: and others respectively for the widows and orphans of clergymen, medical men, officers, artists, and musicians; and for decayed musicians, artists, authors, actors, and schoolmasters: 4. Society for relief of persons confined for small debts: 5. Society for ameliorating the condition of the poor. With these benevolent establishments may be classed the friendly or benefit societies, of which there are in the metropolis and its vicinity about 1600, consisting, in general, of from fifty to one hundred members each. The members consist of mechanic and labouring people, who, by small monthly contributions, raise a fund for their support in sickness, and for their funerals, &c. An act of parliament was passed 33 Geo. III. for the special "Encouragement and Relief" of these societies.

Places of Public Amusement.—Considering the vast extent, population, and wealth of London, it certainly contains fewer places of public amusement than any metropolis in Europe. Whether this be the result of accidental causes, or is to be referred to the genius and habits of the people, may, perhaps, be a matter of some doubt. But whatever deficiency exists with respect to number, it yields to no city in the world in the splendour and excellence of those it possesses. Our dramatic authors are not less conspicuous for the brilliancy of their compositions, than our actors are for the judgment and effect which they display in their representation. Mrs. Siddons is, perhaps, the most effective and powerful actress of the present, or of any former age; while her brother, Mr. John Kemble, must be allowed to possess talents of the first-rate description. In the walk of tragedy many other players have evinced very considerable abilities: among the deceased may be named Garrick, Barry, Betterton, Henderson, Booth, Quin, Ryan, and J. Palmer: and those of the present age, most entitled to historic record, are Cooke, Young, and C. Kemble. It may be safely asserted that the comedians of the London theatres have advanced the mimetic art nearly to the height of perfection. The names of the late Messrs. Lewis, King, Parsons, Woodward, Shuter, and Edwin are justly honoured in the annals of the drama; and those of the following actors are entitled to the unequalled commendation of the theatrical critic: Dowton, Munden, Bannister, Fawcett, Emery, Knight, Matthews, Johnson, Lovegrove, Liston, Simmons, and Blanchard. Many

actresses of the present age possess very considerable dramatic powers; particularly mesdames Jordan, Edwin, Duncan, C. Kemble, Gibbs, S. Booth, Davenport, Liffon, and Storace. The English stage has many other performers of merit; but their talents are of a more limited nature than the preceding. In the operatic department, or singing, it has long been the fashion to introduce Italian, or foreign singers to the London boards; although many of our native performers unite to fine and powerful voices much science. Mrs. Billington, Mr. Braham, Madame Storace, Mrs. Mountain, Miss Bolton, Mrs. Martyr, Mrs. Bland, Mrs. Dickons, Miss Kelly, Mr. Incedon, Mr. Phillips, and Mr. Bellamy, are justly admired, and have acquired much professional fame. In action or pantomimic representations, many eminent performers are to be found on the London boards. Besides these there are many others very little inferior. Indeed it may be justly observed, that the companies at the principal theatres consist in general of highly respectable performers. The musical votary never had the means of gratifying his taste with a higher relish than at the present period. New compositions of considerable merit daily issue from the press. The list of our vocal performers comprises the names of some of the first singers in Europe. Our instrumental performers are no less celebrated; and our bands in general exhibit specimens of the highest taste and manual skill.

Appropriated chiefly to dramatic performances are the theatres of Drury-lane, Covent-garden, the Lyceum, and the Haymarket. Of these, the two first are upon a style of magnificence and grandeur, scarcely to be surpassed by any theatre in Europe. The last is on a small scale, and opens in summer, when the others close. The King's theatre, or Opera-house, situated in the Haymarket, was originally intended solely for the representation of Italian operas. Of late years, however, dancing has constituted a prominent part of its amusements, to the great injury of the operas, which are generally curtailed of an act to allow time for the ballets. The decorations of this theatre are splendid, and its band is considered as inferior only to that of the Opera-house at Paris. The concert of ancient music, generally called the King's concert, is held in the great room Hanover-square, every week from the beginning of February to the end of May. It owes its origin to a secession from the Academy of Music, another celebrated musical institution. The following is a list of the theatres, and other places of public amusement, now occupied in London, and open to the public; a more particular description of some of these will be given in subsequent parts of this work, under the heads THEATRE and WESTMINSTER.

Covent-garden Theatre is the most eminent for size and dramatic exhibitions. The present building was erected in the year 1809, from designs by Mr. Smirke, jun. architect. It occupies the site of a former theatre, with connecting houses, which were consumed by fire in September 1808; and it is worthy of remark, that the whole of the present edifice was raised and finished within one year. It is on a large scale, and the whole stage management is vested in Mr. John Kemble, who has certainly made many improvements, and interesting reformatations in the internal economy, science, and costumic representation of dramas.

Drury-lane Theatre is now in the progress of building from designs by Mr. B. Wyatt, architect; whose model evinces much skill and judgment. Though not on so large a scale as the theatre of Covent-garden, it combines many conveniences and advantages not to be found in that building; and for seeing and hearing it promises to be very satisfactory to the audience. Mr. Whitbread has taken a very active part in causing this theatre to be rebuilt. A former theatre, built by Mr. Holland, was burnt in 1809.

Theatre Royal Haymarket is a small, inconvenient house, and is allowed to be opened to the public from the 15th of May to the 15th of September.

The Lyceum Theatre, called the *English Opera-house*, is at present occupied by the Drury-lane company of performers, under the management of Mr. Arnold and Mr. Raymond. Operas and comedies are chiefly represented here; and some of these are acted in the best style. Many new dramas have been produced at this house.

The Opera-house, in the Haymarket, is appropriated to Italian operas, spectacles, and dances. The management of this house has occasioned several legal litigations, and is still involved in dispute. Its principle is uncongenial to the English character, and it would be a memorable and laudable act to abolish it. Another similar establishment, arising out of the cabals of the former, and originating with some speculating adventurers, has lately been opened at

The Pantheon in Oxford-road; but after a few nights representation, and after debts of some thousands of pounds had been contracted in fitting up, and adapting the house to the purpose, the theatre is again closed.

Sadlers Wells is a theatre appropriated to pantomimes, burlettas, spectacles, dancing, &c. and commences its season on Easter Monday. The stage performances are invented and written by Mr. C. Dibdin, jun., who has displayed a peculiar and original talent in this species of composition. The musical department is conducted by Mr. Reeve, and the scenery painted by Mr. Andrews. A novelty has been introduced at this theatre, *i. e.* of filling the whole space beneath the stage with water, by which means some splendid and curious aquatic exhibitions have been displayed. It partly resembles the naumachia of the Romans.

Alley's Amphitheatre, near Westminster-bridge, is also a summer theatre, where pantomimes, burlettas, and various fetes of horsemanship are displayed. This house also commences its season on Easter Monday, and generally closes in October, when the company remove to another theatre, called

Alley's Olympic Pavilion, in Newcastle-street, where the same species of entertainments are exhibited.

The Surrey Theatre, in St. George's-fields, is devoted to a similar class of dramatic representations; but since Mr. Elliston has been proprietor and manager of this house, he has adopted a novelty, in abridging and verifying many celebrated dramas, and playing the same with the accompaniment of music.

Another theatre in Wellclose-square, called the *Royalty Theatre*, is occasionally opened; and others are situated in Tottenham-street, in the Strand, and in Bridges-street, Covent-garden.

Vauxhall Gardens are opened twice a week in the summer months, when they are ornamented with an immense number of lamps, and a large concourse of visitors are entertained by vocal and instrumental music. Besides the foregoing, London abounds with many other places of amusement; such as tea-gardens, exhibitions for ingenious inventions, and display of works of fancy, &c.

Among the places of public amusement or exhibitions, may be specified—

The London Museum, in Piccadilly, the property of Mr. W. Bullock, who has devoted many years, much exertion, and a great expence, in collecting and arranging the most comprehensive and interesting assemblage of natural and artificial curiosities that was ever before amassed in England, or perhaps in Europe. His museum was originally commenced at Liverpool; but it has been progressively enlarged and improved. Its preserved specimens in natural history are select, in the highest preservation, and arranged accord-

ing to the Linnæan system. They consist of about 15,000 quadrupeds, birds, reptiles, fishes, insects, corals, &c. One department of the museum is peculiarly curious and interesting. It is called the Pantherion, in which most of the known animals, in a preserved state, and in natural attitudes, are exhibited as ranging in their native, or appropriate haunts; and exact models of exotic plants, rocks, and trees, are dispersed over the apartment: the whole interior of the same is painted in a panoramic manner, representative of oriental scenery. For a particular account of this truly interesting collection, the reader is referred to a printed "*Companion to the Museum and Pantherion*," 12mo. 2s. 6d. or to a larger work, with etchings, by Howitt, price 14s. A new building, in the Egyptian style, has been erected for this museum from designs by Mr. Robinson, architect.

Polito's Museum, at Exeter Change in the Strand, contains a choice collection of living beasts and birds; and to the students and lovers of natural history is very interesting. Here are lions, leopards, tigers, ostriches, baboons, and monkeys of different kinds, kangaroos, beavers, and various other foreign animals and birds. Other museums and exhibitions of natural and artificial curiosities are—

Dubourg's, in Grosvenor-street, for cork models of several temples, and ancient buildings in Rome:—*Maillarde's* automatic exhibitions in Spring-gardens, for some singular works of mechanism:—*Week's Museum*, Haymarket, is also for mechanical works. At *Barker's Panorama*, in Leicester-square, are exhibited circular views, on a large scale, of several foreign and English cities, towns, and other particular scenes. Mr. Barker has evinced very considerable taste and talents in this branch of art, and to him the public are indebted for the first invention of panoramic views. Since he commenced, several other artists have exhibited similar pictures: Mr. Girtin, a view of London; Mr. Porter, several paintings of battles, and a *New Panorama* is now opened by Reinagle and Barker, in the Strand. See PANORAMA.

The *Fine Arts*, and *Exhibitions of Works of Art*, in London, are entitled to distinct and particular notice; for their present state is calculated to shew the extraordinary progress they have made during the last century, and to display the highly cultivated condition of the present age. London is the focus of the fine arts of England, and fountain-head of excellence. Here all the eminent artists of the country either originate, are educated, or terminate their career; because all the great masters reside here; the best instruction is to be obtained; the most celebrated productions to be seen and studied; and annual exhibitions displayed to the public. In the rooms of the Royal Academy at Somerset-house, in those of the British Institution, Pall-Mall, at Spring-gardens, and in Bond-street, are annual exhibitions of paintings, drawings, sculptural and architectural designs; and a careful examination of the works here exhibited will furnish a foreigner with ample means to appreciate the individual and aggregate merits of English artists. Besides these public exhibitions, it will be expedient to visit the galleries of Mr. West, Mr. Turner, Mr. Wilkie, Mr. Lawrence, and some other painters; for in these will be found several of the most meritorious works of the age. The best productions of our modern sculptors will be found in the church of St. Paul's and in Westminster Abbey; whilst the true talents of the architects can only be appreciated by a personal examination of the buildings they have erected. The public institutions devoted to the fine arts are the following:

At the *Royal Academy*, in Somerset-house, is an annual exhibition, for the period of about six weeks, of paintings, drawings, sketches, models, and proof-prints. This academy was established by charter in the year 1768, and Sir Joshua

Reynolds appointed its first president. To this great artist's talents as a painter, conduct as a man, and writings on art, the Royal Academy is essentially indebted for its prosperity and reputation. His fascinating productions, engaging manners, and luminous discourses on painting, attracted the attention and patronage of many persons of distinction, and at the same time roused the emulation and active zeal of the junior artists. Since Sir Joshua's time, Mr. West has occupied the presidential chair, with little interruption, and has honoured the academic exhibitions with a continued succession of new pictures in the highest branch of art. A series of lectures has been annually given at the academy by different professors; all calculated to advance art, and inculcate proper principles of taste and criticism. Some of the present lecturers are deservedly famed for professional science, as well as for general knowledge. In the years 1811 and 1812, the following professors delivered lectures on their respective provinces of art: Henry Fuseli, on painting; John Soane, on architecture; Anthony Carlisle, on anatomy (it is necessary to state that this gentleman is not a member of the academy); J. M. W. Turner, on perspective; and John Flaxman, on sculpture. The Royal Academy consists of forty members, called Royal Academicians, twenty associates, and six associate engravers. Further particulars of this institution will be given under *ROYAL ACADEMY*.

The *British Institution*, in Pall-Mall, was established by the liberal contributions of several noblemen and gentlemen in the year 1805, for the express encouragement of British artists: and it must afford much gratification to the founders to contemplate its great utility and successful effects. This institution is devoted to the exhibition and sale of pictures; and to the use of young students for copying from and studying old paintings. Another plan has been recently adopted, which is calculated to enhance its utility and reputation. This is the purchase of pre-eminent pictures, which are to be preserved as the property of the institution, and from which engravings are to be made on a large scale. The first of this series is a large painting by Mr. West, of "Christ healing the Sick in the Temple!" and Charles Heath is engraving a plate from it.

The *Society of Painters in Water-Colours* was established in November 1804, since which time they have annually exhibited a large and interesting collection of drawings. This branch of art may be said to have attained nearly the highest excellence; and many of its professors have manifested distinguished talents. In colouring, effect, and appropriate character, several young artists of the present age have surpassed any of the old masters in this branch of art. Another society of artists have made an annual exhibition of drawings in Bond-street. The collections of pictures in private houses in London are numerous, and many of them very valuable. The most celebrated of these are the marquis of Stafford's, at Cleveland House; (for an account of these pictures, see Britton's "*Catalogue Raisonné*," and Trefham's "*Gallery of Pictures*;") the collection at Buckingham-house; the earl of Grosvenor's, in Grosvenor-street; Mr. Thomas Hope's, in Dukes-street; Mr. H. W. Hope's, in Cavendish-square; Mr. Anderdon's, Spring Gardens; Mr. West's, in Newman-street; earl of Suffolk's, in Harley-street; the duke of Devonshire's, in Devonshire-house; Mr. Angerstein's, Pall-Mall; Sir Abraham Hume; Sir George Yonge, in Stratford-place; Lord Northwick's, in Hanover-square; Mr. Weddell's, in Upper Brooke-street; Lord Ashburnham's, in Dover-street; baroness Lucas, in St. James's-square; Sir George Beaumont, in Grosvenor-square; Mr. William Smith, in Park-street; Mr. Knight, of Portland-place; Mr. Jeremiah Harman, of Finsbury-square; Mr. R. P.

Knight, of Soho-square; lord Radstock, in Portland-place. Besides these, there are many other collections of fine pictures in various parts of the metropolis. For much useful information respecting the fine arts in London, &c. see Hoare's "Inquiry into the present State of the Arts of Design in England," 8vo. 1806; also two other volumes in 4to. edited by the same intelligent and liberal writer, entitled "The Artist, in a Series of Essays;" also, "The fine Arts of the English School," 4to. 1812; Britton's Preface to an Account of the Cornham-House Collection; and Edwards's Anecdotes of Painters in England, 4to. 1808.

Courts.—For an account of the various courts of London, the reader is referred to a former volume, under the head *COURT of Common Pleas, of Chancery, of Exchequer, of Husting, of King's Bench, of Marshalsea, Mayor's, of Parliament,* (see *PARLIAMENT*;) *of the House of Peers, of Star Chamber;* also, *Inns of Court.*

Literature and literary Publications.—To give a view of the literature of this metropolis, and to point out its present state, compared with that of any former period, would be to develop one of the most interesting traits, not only of London, but of the present age. The number and variety of works which annually issue from the metropolitan press are truly astonishing; while in point of ability and usefulness they were probably never exceeded. There is not indeed a department, either in science or general literature, which has not made considerable progress within these few years. The publishing and bookselling businesses are at present conducted upon very large scales; and, in spite of a long and devastating war, a succession of new and interesting volumes is continually issuing from the press. It is conjectured that nearly 800 new books and pamphlets have been annually published in London, during the last ten years: the gross annual returns arising from the printing and selling of which cannot be much short of one million sterling. It is also estimated that 2000 persons at least are directly and collaterally employed in the various branches of the book business. The character and extent of periodical literature form a prominent feature of the present age: for the number of reviews, magazines, newspapers, and other periodical journals, far exceed those of any former period. Hence much political and general knowledge has been disseminated through the country; a spirit of inquiry and investigation has been excited; and a literary turn has been given to the higher and middle classes of society. Even the lower classes of mechanics and servants are now much accustomed to reading: one of the consequences arising from which is that we frequently hear of men of genius and talents starting up from humble stations, and displaying to the astonished world much originality of thinking. Many instances of this might be adduced; but it will be sufficient to name two or three, to prove the assertion: Burns, Dermody, and Bloomfield, the poets; and Drewe, the metaphysician of Cornwall. Nothing can more plainly shew the reading character of the present times, than a knowledge of the number of newspapers printed and circulated; and which number is thus stated in "The Picture of London for 1812:" "Of the morning papers, there are sold about 17,000 of these publications; of the daily evening papers, about 12,000; and of those published every other day, about 10,000. There are also about 26,000 sold of the various Sunday papers; and about 20,000 of the other weekly papers: in all, the enormous number of 232,000 copies *per week*; yielding to their proprietors from the sale 5800*l.*, and from advertisements 2000*l.* more; of which the revenue to government is 4000*l.* and the net proceeds to the proprietors about 3000*l.*; the remaining 2800*l.* affords employment and sub-

sistence to about 50 writers and reporters, 300 printers, 100 vendors, and 100 clerks and assistants; besides paper-makers, stationers, type-founders, &c. full 200 more. If to these be added the weekly calculation of 250,000 copies of provincial papers, yielding 10,000*l.* *per week*, and supporting the industry of 1500 persons;—what a wonderful idea is afforded of the agency and influence of the press in this empire; and how easily is it accounted for, that we are the most free and most intelligent people on the face of the earth." Under the words *MAGAZINE, NEWSPAPER, and REVIEW*, we shall have opportunities of detailing many facts and peculiarities respecting these different publications. See also *JOURNAL, Literary.* London abounds with booksellers' shops and circulating libraries. It is asserted that the first circulating library established in this town was by a Mr. Bath, about the year 1740; but Alan Ramsay had founded one at Edinburgh as early as the year 1725. In London there are published seventeen newspapers daily, and eighteen or nineteen every Sunday, besides eighteen once or twice a week. The number of monthly magazines and reviews amounts to fifty; in addition to which, there are several works published quarterly, or at irregular periods.

Societies for the Encouragement of the Arts, Sciences, &c.—London possesses a variety of institutions formed with a view to the advancement of the different branches of art and science; among these the Royal Society undoubtedly takes the lead, being composed of the most distinguished literary and scientific characters of the present age. It was first instituted at the close of Cromwell's rebellion, at which time its meetings were held at Oxford. In 1659 they were adjourned to Gresham college, London; but of late years have been held at an apartment in Somerset house. This society was incorporated in 1663, when the celebrated sir Isaac Newton was president, and has, through the medium of its Transactions, and by its patronage, probably contributed, more than any similar body in the world, to promote useful and practical knowledge. (See *ROYAL SOCIETY*.) The society of Antiquaries, which holds its meetings in the same place with the Royal Society, was incorporated by Geo. II. in the year 1751. The object of this society is to encourage research in the elucidation, not only of our national antiquities, but of the antiquities of other countries. It has published sixteen volumes, called the *Archæologia*, containing many curious and interesting essays and prints, also a large work illustrative of our ecclesiastical architecture. (See *SOCIETY of Antiquaries*, and *ANTIQUARY*.) The society for the encouragement of arts, manufactures, and commerce, instituted in 1753, and holding its meetings in the Adelphi, proposes the attainment of its object by giving premiums for all inventions and discoveries which may prove, and are calculated to be, beneficial to the arts, commerce, or manufactures of the kingdom, the British colonies, or the East India settlements. A volume of the Society's transactions is published occasionally. The walls of the great room, in which its meetings take place, are adorned with a variety of paintings from the pencil of Mr. Barry, the style and execution of which have insured him deserved immortality, and are really an honour to the country. The Linnæan society was founded in 1788, and incorporated in 1802. (See *Linnean SOCIETY*.) The Royal Institution, situated in Albemarle street, owes its foundation chiefly to the schemes and exertions of count Rumford. Its charter of incorporation is dated in 1800. The original object of this institution was to facilitate the introduction of useful discoveries and improvements in practical mechanics, and to point out, by philosophical lectures and experiments, the application of science to the common purposes of life. The investigations and important discoveries of Dr. Davy, the

lecturer on chemistry, have conferred no small degree of celebrity on this establishment, while they will not improbably be the means of effecting a complete change in our views of chemical analysis. (See *ROYAL INSTITUTION*.) The London Institution, as well as the Surrey Institution, embrace similar objects to the one preceding. The former was founded in 1805, and the latter in 1808. Both have extensive libraries and reading rooms, furnished with many of the foreign and domestic journals and other periodical works, together with the best pamphlets and new publications. The views of the Ruffel Institution are the formation of an extensive library, consisting of the most valuable books in ancient and modern literature, to be circulated among the proprietors, the delivery of lectures on literary and scientific subjects, and the establishment of a reading room. In Gresham college, founded by sir Thomas Gresham, lectures are delivered gratis twice a day during the terms, on divinity, law, physic, astronomy, geometry, music, and rhetoric. As it happens in all institutions on a similar plan, the lecturers, having no stimulus to exertion, consider their duty as a mere matter of routine, and are consequently ill attended. Some idea is entertained of transferring them and the funds to the London Institution, where it is hoped they may be more efficient, and answer better the design of the benevolent founder. The British Mineralogical Society was established in 1799, for the express purpose of examining gratuitously the composition of all specimens of minerals and soils, sent for that purpose by the owners of mines, agriculturalists, or others interested in the enquiry. The science of entomology will probably be much forwarded by the institution of the Entomological Society, which took place in 1806, and which chiefly directs its attention to the investigation of the properties of such insects as are natives of the united kingdoms. The London Architectural Society has published a volume of Essays, 8vo. 1808: also an Essay on the Doric order. The Horticultural society was founded in 1804. A Geological Society is established by some scientific gentlemen in Lincoln's-in-Fields; they have recently published an interesting volume of their transactions. Before we quit these institutions it may be proper to remark, that the number and variety of lectures that have been read in them must have proved beneficial to science; by exciting inquiry, and investigating facts by experiment. Till these institutions were established, there were but few public lectures given in London; such, however, have been the influence and effect of them, that during the winter of 1811-12, it may be asserted that no less than fourteen courses have been given at the Royal, Ruffel, and Surrey Institutions. We subjoin the names of the principal professors: Dr. Davy, Dr. Roget, Dr. Crotch, J. M. Good, esq., Geo. John Singer, esq., Dr. Shaw, F. Accum, esq., Sam. Weitley, esq., Mr. Hardie, Robert Bakewell, esq., Dr. Brande, James Quin, esq., John Poad, esq., and Wm. Haslitt, esq.

The British Museum, situated in Great Ruffel-street, is a grand national depository of antiquities, MSS. and books, with various natural and artificial curiosities. It was established by act of parliament in 1753, in consequence of sir Hans Sloane having left, by will, his museum to the nation, on condition that parliament paid 20 000*l.* to his executors, and purchased a house sufficiently commodious for its reception. Since that period many valuable collections of manuscripts, books, &c. have, at different times, been added to the Sloanean, besides innumerable presents from our own monarchs, foreign princes, the boards of Admiralty and Longitude, the East India Company, the various literary societies of London, Edinburgh, Oxford, Cambridge, and Leyden, the Royal

and Imperial academies of Brussels, Lisbon, &c. and a long list of private individuals, too numerous to be particularized. The vast variety of articles which this museum contains, its extent and value, entitle it to be considered equal to any in the world. Under the word MUSEUM will be given further particulars of this national repository; in the mean time the reader is referred to a "Synopsis of the Contents of the British Museum," 8vo. 1808; and to a quarto work of "Engravings from the Gallery of Antiquities in the British Museum," by Mr. Taylor, Combe, and Mr. Alexander. This very handsome and interesting work is now in the progress of publication, and is very creditable to the trustees who have commenced it, and to the draftsman and author by whom it is chiefly executed.

Public Vices and Prisons.—The general tendency of the preceding statements only shew the best and most interesting features of the metropolis. It is our duty also to depict its vices; and to shew the numerous places that are set apart for the punishment of crimes. In Colquhoun's work on "the police of the metropolis," is such a deplorable display of profligacy and criminality, that an inexperienced reader, who knew London only through the medium of this publication, would conclude that its inhabitants were mostly composed of vagabonds, sharpers, pickpockets, and prostitutes. It should be remembered, however, that the work is chiefly devoted to this subject; and that, amidst so vast a population, and where there are so many opportunities for rogues to practise their depredations, and screen themselves from detection, it is not surprising that so many are collected together, and that out of a great number so few are brought to condign punishment. To this great hive of human society, the most vicious, and also the most learned resort, as the best place for action and exertion. The worthy magistrate already named, has enumerated and described eighteen different classes of cheats and swindlers who infest the metropolis, and prey upon the honest and unwary: besides persons who live by gambling, coining, housebreaking, robbery, and those who plunder on the river. He deduces the origin of most of the crimes from alehouses, bad education of apprentices, servants out of place, Jews, receivers of stolen goods, pawnbrokers, low gaming-houses, smuggling, associations in prisons, and prevalence of prostitution. No less than 50,000 prostitutes are supposed to live in the metropolis. An amazing number, and a distressing circumstance to contemplate: for it is presumed that eight-tenths of these die prematurely of disease and in wretchedness, having previously corrupted and contaminated twice their own number of young girls and young men. The following is a list of the public prisons.

1. Newgate, being the city and county goal for debtors, felons, libellers, and other offenders against government. See *NEWGATE*.

2. Giltspur-street Compter was erected in 1791, for debtors, felons, and persons committed for misdemeanors. It is situated near Newgate, and is a large, commodious building.

3. Ludgate, adjoining to the last mentioned, is appropriated only to debtors who are freemen of the city of London, clergymen, professors, or attorneys.

4. The Poultry Compter is chiefly for debtors. It is situated near the Mansion-house, and has one ward set apart for Jews: the only prison in England that has such a provision.

5. The Fleet Prison is for debtors, and for such persons as are committed for contempt of the courts of chancery.

6. The Savoy Prison, in the Strand, is exclusively devoted to deserters and military delinquents.

7. The New Prison, Clerkenwell, is the goal for the county of Middlesex, for felons, and persons fined.

8. The Prison for the Liberty of the Tower of London, is at Bethnal-green, and is used only for soldiers belonging to the Tower.

9. Whitechapel Prison for debtors in the 5*l.* court.

The houses of correction are

10. The City Bridewell, Bridge-street, Blackfriars.

11. Tothill-fields Bridewell.

12. Cold Bath Fields Penitentiary House.

13. New Bridewell, in the borough of Southwark.

14. County goal for Surrey, in the borough of Southwark, for felons and debtors.

15. New goal, Southwark, or Borough Compter, for felons and debtors.

16. Clink goal, for the district of that name, in Southwark.

17. The Marshalsea goal, Southwark, for pirates, and for persons arrested for small debts in the Marshalsea court.

18. King's-bench prison, St. George's Fields, for debtors, and for persons committed for contempt of the court of King's-bench, of which this is the peculiar prison.

Public Buildings.—It will surprise a foreign architect to look through the wealthy city of London, and perceive so few public edifices that display architectural beauty, or grandeur. Various circumstances have conspired to occasion this; and not want of abilities in our artists: for many names can be mentioned, both of deceased and living architects, whose designs would honour and ornament any city. Those whose works are most conspicuous in London, are Inigo Jones, sir Christopher Wren; Gibbs, Hawksmoor, Dance, Soane, Samuel Wyatt, Jupp, sir Robert Taylor, Smirke, Milne, Holland, and Adams. The public edifices of London are bridges, (for an account of which see BRIDGES,) churches, public offices, hospitals, and private mansions. Squares and regular streets constitute a distinguishing feature of town architecture. Some of the public buildings are spacious, commodious, judiciously adapted to their respective purposes, and display beautiful, fine, and even grand parts. The English architect is justly noted for the skill and judgment he often evinces in designing and adapting the interior of his buildings; and this is certainly the most essential part of the profession. The principal public edifices within the precincts of the city, and in the eastern part of the town, are the Tower; the New Mint; the Trinity House; the Bank; the Mansion House; the Royal Exchange; the East India House; the Auction Mart; the Commercial Mart; the Custom House; the Excise Office; Guildhall; the bridges of London and Blackfriars; the Post-office; Newgate; Giltspur-street Compter; St. Luke's Hospital; the churches of St. Paul, Bow, St. Stephen's Walbrook. St. Bride's Fleet-street.

Tower of London.—This celebrated building stands on the north bank of the river Thames, at the eastern extremity, and just without the limits of the city. If credit is to be given to the statement of Fitz-Stephen, it owes its original foundation to Julius Cæsar, but this assertion is supported by no evidence. The first authentic notice of it is, that William the Conqueror erected a fortress here immediately upon his obtaining possession of London in the year 1066, with the view of intimidating the citizens from any opposition to his usurpation. This monarch seems, about twelve years afterwards, either to have much enlarged the previous edifice, or to have built another on its site or near it. This building forms, what is now called, the White Tower, from its having been repaired and white-washed by Henry III. in the

year 1240. It is a large square structure, situated near the centre of the present fortress, and surmounted by four watch towers, one of which is used as an observatory. It consists of three lofty stories, in the first of which are two grand rooms, one of which is a small armory for the naval service. The other buildings and fortifications have been erected at different periods. The principal of the former are, the church dedicated to St. Peter *ad vincula*; the ordnance office; the mint; the record office; the jewel office; the horse armory; the grand store-house; the new or small armory houses belonging to the officers of the Tower, and barracks for the garrison. The whole comprises, within the walls, an extent of twelve acres and five roods. The exterior circumference of the ditch, which entirely surrounds it, measures 3156 feet. This ditch, on the side of Tower-hill, is broad and deep, but becomes much narrower on that nearest the river, from which it is divided by a handsome wharf, having a platform upon it, mounted with sixty-one pieces of cannon. Besides these, there are a number of great guns, arranged as small batteries, on different parts of the walls. The chief entrance is by a stone bridge thrown over the ditch on the west-side of the Tower. At the outer extremity of this bridge are two gates, and within the ditch another, all which are shut every night, and opened in the morning with particular formality. The wharf is connected with the Tower by a drawbridge, near which is a cut leading from the ditch to the river, secured by a gate called Traitor's Gate, from the circumstance of state prisoners having been formerly conveyed by this passage to Westminster for trial.

This fortress was a palace, inhabited by various sovereigns of England till the reign of queen Elizabeth. Since that period it has been chiefly used as a state prison, and as a place of security for arms and property belonging to the crown. In one of the rooms of the White tower, called Cæsar's chapel, a variety of ancient records of the court of chancery are deposited. All the models of new invented engines of destruction, which have been presented to government, are preserved in another room adjoining. The old mint, and the houses belonging to the officers employed in the coinage, occupied nearly a third of the whole fortress. A yard, to the right of the western entrance, contains the royal menagerie. In the Spanish Armory are kept the trophies of the celebrated victory over the Spanish armada; the axe with which the unfortunate Anne Bullen was beheaded; and a representation of queen Elizabeth, dressed in the armour she wore when she addressed her army at Tilbury, in the year 1588. The Small Armory, one of the finest rooms of its kind in Europe, contains complete stands of arms for upwards of 100,000 men, arranged in a most elegant manner, besides other curiosities. Under this armory is another very noble room belonging to the royal train of artillery, where many beautiful and uncommon pieces of cannon may be seen. The Horse Armory is filled with curiosities of different kinds. Among these are the figures of the kings of England on horseback, chiefly dressed in the ancient armour. In the Jewel Office are preserved the imperial regalia, and all the crown jewels worn by princes and princesses at coronations. Independently of several, which are inestimable, the value of the precious stones and plate in this office considerably exceeds two millions sterling. These, as well as the government of the whole Tower, are entrusted to the care of an officer, called the constable of the Tower, who has under him a lieutenant, deputy-lieutenant, tower-major, gentleman porter, and a number of inferior officers. The garrison is composed of a detachment from the guards. The rising ground adjacent to the

Tower is called **Tower-hill**. The right of the city to this spot was long disputed by the crown, but in the reign of Edward III., some of the king's officers having erected a gallows here, the citizens remonstrated, whereupon that monarch issued a proclamation, which he disavowed in the act, and virtually acknowledged the city's jurisdiction, by delivering over the persons about to be executed to the sheriffs; and desiring that they should preside at their execution. On the site of the old victualling office, to the east of the Tower, an extensive building has been lately erected from designs by Mr. Smirke, jun. for the Mint. It is composed of a long front of stone, consisting of a ground-floor, with two stories above; the whole surmounted by a handsome balustrade. The wings are ornamented with pilasters, and in the centre are several demi-columns, over which is a pediment, decorated with the arms of England. The porch is covered with a gallery, balustrades, &c. all of the Doric order. Adjoining are houses for the principal officers.

Manfion-house.—This building, the residence of the lord mayor of London, is situated to the west of Lombard-street and Cornhill. It is of an oblong form, and constructed of Portland stone. From its massive style and vast extent, it is calculated to make a magnificent appearance, but the effect is destroyed by its confined situation. A wide and lofty portico, composed of six fluted pillars of the Corinthian order, with two pilasters at each side of their pediment, of the same order, form the chief ornament of the front. Under this portico is a low basement story, in the centre of which is the gate-way leading to the kitchen and offices. A flight of steps ascends to the principal entrance door-way beneath the portico. These stairs are inclosed by a stone balustrade, continued along the whole length of the front. The pediment of the portico is adorned with a piece of sculpture emblematical of the wealth and grandeur of the city. In the centre is a female figure representing the city, having a wand in her right hand, and her left resting on the city arms. On her head is a mural crown, and under her left foot a figure of Envy. Near her on the right is a cupid, with the cap of liberty affixed to a short staff, leaning on his shoulder, and beyond him reclines a sea god, to represent the Thames, having at his side an anchor fastened to a cable. To the left of London is Plenty, with a cornucopia, and behind her two naked boys, with bales of goods to denote Commerce. The west side of this edifice presents a range of very noble windows, placed between coupled Corinthian pilasters. Its interior exhibits a sufficient degree of splendour, but is far from being comfortable, as many of the rooms are dark. Some of the apartments are very large, and fitted up in a sumptuous style; particularly the Egyptian hall, the ball-room, &c.

Commercial Hall.—It has long been a complaint in the city that some respectable place of general accommodation was wanted for the disposal of imported merchandize, but principally for that of colonial produce. Several attempts have been made to remedy this defect, but without success. About a year ago, Messrs Smith, Marten, and St. Barbe called a meeting of merchants and brokers, in order to establish an institution for this purpose. A large subscription was raised almost instantly, and as soon as a plot of ground, sufficiently large, and in a suitable situation, could be procured, a number of plans were submitted by different architects, from an examination and comparison of which, a new design was formed and carried into execution under the direction of J. Woods, jun. whom the committee chose for their architect. The original intention of the establishment was

principally for the accommodation of public sales, but it has been extended to provide equal conveniences for sale by private contract; and thus to form a complete market for sugar, cotton, coffee, tobacco, indigo, and other imported goods.

The building is composed of two principal parts. The front consists of an entirely new edifice, 64½ feet long, and 39 feet broad, with a stone front, ornamented with six columns of the Ionic order, adopted, with little variation, from the temple of Minerva Polias, at Priene. These columns are supported on pedestals, which rest on the cornice of an inferior order, composed not of columns but of piers, whose squareness and solidity form a contrast with the lighter and more varied proportions of the columns above. This order of piers forms the ground story of the building. The spaces between the pedestals are filled up with balusters, and above the windows, which are large and suited to the scale of the building, are five bas-reliefs, executed in artificial stone by Bubb: the middle compartment representing the city of London, the four others, Navigation, Commerce, Agriculture, and the Arts. The whole of the ground-floor of this edifice is occupied by a magnificent coffee-room, at one end of which, between two columns, appear the stairs leading to two public sale-rooms, one of which is about 35 feet by 30, and again on the upper floor to three more sale-rooms, each about 25 by 20 feet.

The second building formerly consisted of three houses, which are now thrown into one: the lower floors are divided into a number of counting-houses, the upper into five show-rooms, the largest of which, sixty feet long, is appropriated for the exhibition of goods intended for sale.

Particular attention has been paid to the lights in these rooms, and by a succession of sky-lights sloping to the north the perfect light of day is admitted, and the sun effectually excluded. The space between these buildings, and that behind the latter on the ground-floor, is occupied by a number of rooms lighted in the same way, all of which are intended for the sale of sugars.

The object of this building is the attainment of public convenience; by bringing into one point what before had been scattered among several coffee-houses, and the rooms of individuals.

East India House.—This edifice is situated on the south side of Leadenhall-street, and comprises the principal offices of the East India Company. It was originally founded in the year 1726, but has recently been so much altered and enlarged, under the superintendence of Mr. Jupp, architect to the company, as to appear like an entire new building. The front, composed of stone, is very extensive, and displays a general air of grandeur and simplicity. In the centre rises a noble portico, supported by six Ionic fluted columns. The frieze is sculptured with a variety of antique ornaments, and the pediment exhibits several figures emblematical of the commerce of the company, protected by his majesty, who is represented in the act of extending a shield over them. On the apex of the pediment is placed a statue of Britannia, to the east of which is a figure of Asia, and on the west another of Europe. The interior can boast of several very noble apartments, particularly the sale-room, which may be justly reckoned among the curiosities of the metropolis. In this house the courts of the East India Company are held, and all its official and general business transacted. Several large and commodious warehouses are distributed in different parts of the town, where teas and other imported goods are deposited. See **COMPANY, East India**.

The London Monument—This noble pillar, perhaps the finest in the world, stands on the east side of Fifth-street-hill, about two hundred yards from the north end of London-bridge. It was erected by the celebrated sir Christopher Wren, to commemorate the dreadful fire of 1666, which destroyed a great part of the city, and commenced near this spot. This monument is a fluted column of the Doric order, with a base and capital, surmounted by a ball. Its diameter at the base is fifteen feet. The massy pedestal measures 40 feet, the column 120, the cone above it, with its urn, 42, so that the entire height of the pillar is 202 feet. The interior contains a flight of 345 steps, ascending to a balcony, from which the visitor has a very extensive prospect of the metropolis and the adjacent country. The obscure situation of this beautiful and majestic pillar is much to be lamented, for were it placed in a conspicuous position, it would form a great and striking ornament to the metropolis.

The Post-Office is situated in an area on the south side of Lombard-street. As a building, it is not only unworthy of notice, but when the importance and magnitude of its concerns are considered, is really a disgrace to the country and the metropolis. Such an important establishment should be well and properly accommodated. As a national institution, however, it deserves particular attention, being perhaps the most perfect system of internal economy, of its kind, in the world: it keeps up a constant communication, directly or indirectly, with every town in the united kingdom, as well as with every foreign port in the most remote degree connected with the British empire. It possesses likewise the double advantage of being incalculably useful to individuals, and affording a large revenue to the government. Indeed, of all the means of finance any minister ever employed, it is beyond comparison the best; while at the same time it may justly be regarded as the soul of commerce. The present post-office was built in 1760, but since that time great additions have been made to the building. At the commencement of the post-office system, the whole was vested in private persons, and was irregular, defective, and insecure. A few years back a very important plan was suggested by Mr. Palmer, of conveying letters to all parts of the kingdom by means of mail coaches; whereby a speedy communication, and security from robbery were effected. See *MAIL COACHES*, and *POST-OFFICE*.

The Trinity House.—On the north side of Tower-hill is a large, handsome, regular building, which was erected from designs by Samuel Wyatt, architect. The chief business of the Trinity-house corporation, which was founded in 1512, is conducted here, though the old established house is at Deptford. The corporation consists of one master, four wardens, eight assistants, and twenty-eight elder brethren, who are styled "the guild, or fraternity of the most glorious and undivided Trinity, and of St. Clement, in the parish of Deptford-Strond, in the county of Kent." The object of this corporation is to superintend and guard the interests of the British shipping, both military and commercial. Their powers are extensive; and their objects important. They have to examine the children who are instructed in mathematics in Christ's hospital; examine the masters of the king's ships; appoint pilots for the Thames; erect light-houses and sea-marks in the British seas; grant licences to poor seamen who are not free of the city, to ply for fares on the Thames; superintend the deepening and cleansing of the river, &c. The Trinity-house contains some handsome apartments, particularly the hall, the stair-case, and the court-room; in one of which is a fine model of the ship

called the Royal William; also portraits of twenty-four of the elder brethren, and of other eminent persons.

The Lunatic Hospital, called St. Luke's, in Old-street, a large pile of building, was erected from designs by George Dance, who also built the prisons of Newgate and the city Compter. In all these he manifested much skill and judgment; but there is a great want of both in the new front.

The Guildhall of the city is a piece of architectural absurdity.—It is appropriated to the chief public offices of the corporation of London: the principal of these is the great hall, (153 feet long, by 48 broad and 55 high,) in which the large city feasts are held, where public meetings are assembled, and the lord-mayor and members of parliament elected. Here are several portraits of sovereigns, judges, lord-mayors, &c.; also large marble monuments to the justly esteemed lord-mayor, Beckford, the great lord Chatham, &c. Besides the hall, the following offices are included in the present building; chamberlain's-office, the court of king's bench, in which the lord-mayor's court and sessions of the peace for the city are held; a court of common pleas, and court of exchequer; a court, called common council chamber, for the lord-mayor, aldermen, and common council. Attached to the Guildhall is an old chapel, which formerly belonged to a religious establishment, but is now used as a justice-room for the aldermen.

The Bank of England, an immense pile of building, is more extensive in its range of offices, and more eminent for its architectural adornment and interior arrangement, than any single public edifice in the metropolis: for Somerset-house, or place, consists of various offices, dwelling-houses, &c. It presents an irregular and incongruous medley of styles and forms; having been built at various periods by three different architects. The oldest part, i. e. the centre of the principal, or south front, with some apartments on the same side, was designed and erected by George Sampson, in the year 1733: and the lateral wings of this façade, and the returns on the east and west sides, with several offices immediately attached, were built by sir Robert Taylor, between 1770 and 1786: but the great alterations and additions that have been made since the year 1788 by Mr. Soane, constitute the prominent features of this noble edifice. It would occupy a volume to describe the whole arrangement and extent of the bank: it must suffice on the present occasion to mention a few of its leading characteristics. The whole buildings are included in an area of an irregular form, the exterior wall of which measures 365 feet in front, or on the south side; 440 feet on the west side; 410 feet on the north side, and 245 feet on the east side. This area comprises eight open courts, one rotunda, or circular room, several large public offices, committee rooms, and private apartments for the residence of officers and servants. The principal suite of rooms is on the ground-floor, and there is no floor over the chief offices; but it is necessary to state, that beneath this floor, and even below the surface of the ground, there is more building, and more rooms than above-ground. Part of the edifice is raised on a marshy, soft soil, for the stream called Wallbrooke ran here, and it has been necessary to pile the foundation, and construct counter arches beneath the walls. The following is a list of the principal public rooms, with their dimensions: on the southern side, dividend-pay office, 44 by 40 feet; the three *per cent.* reduced office, 50 by 40 feet; pay-hall, 40 by 70 feet; stock-office, 60 by 45 feet: three others of nearly the same dimensions; the rotunda, 55 feet in diameter; the consol office, 80 feet by 48, is a noble room; court-room, 60 by 30 feet, ad-

joining which is the great committee room; office for notes under 5*l*, 60 by 40 feet; and the chief cashier's office, 45 by 30 feet. Besides these, the Bank contains many other offices and apartments; among which may be named the secretary's office, bullion office, deputy governor's rooms, general cash-book office, out-teller's office, land-tax redemption office, loan, or property office, drawing office, accomptant's office for the new specie, cheque office, reduced annuity office, dividend pay-office, armoury, bank-note printing-office, engraver's rooms, the library, &c. Such is the extensive business of the bank, that above 1000 persons are employed in its various offices. Of the architectural characteristics of this edifice, its extent, arrangement, and adaptation to the accumulated and increasing business of the British bank, it will be impossible to convey satisfactory information, in a limited space, and without illustrative prints. We can only briefly describe a few of the principal features. The oldest part by Sampson, combines a degree of simplicity united with grandeur; and was admirably adapted to its original purpose. It bespoke the character of a public edifice, with a rich and appropriate style of design. The whole assumed an air of dignity and importance, with a sufficiency of ornament and dress. On a rusticated basement are two stories with Ionic columns, and a bold entablature. An uniformity of character pervades the whole. With such a model before him, it is astonishing that Sir Robert Taylor did not design his additions in the same style, or in one that harmonized with it: but it seems evident that he did not feel or appreciate the charms of simplicity. He preferred prettiness to propriety, and gaiety to grandeur, and therefore designed the wings, with the offices immediately attached, in the most gorgeous style of Roman architecture. Corinthian fluted columns, arranged in pairs, are placed along the whole front, supporting pediments at both extremities, and a balustraded entablature between.

In this façade, the architect has copied a building of Bramante in the Belvidere gardens at Rome; but this very circumstance impeaches his taste and judgment. For though the style and design might have been appropriate and judicious in a small ornamental building, it is very absurd in a great national structure, where solidity, security, and simple grandeur were required. The four and five *per cent.* stock offices are truly disgusting, as works of art; and also very defective as rooms for business. They are both exact imitations of the interior of the church of St. Martin's-in-the-Fields. The forms and proportions of the exterior columns much excite our admiration. In the additions and improvements made to the bank by Mr. Soane, since his appointment in 1788, we find many novelties in design, and skillful appropriations. The rotunda is a spacious circular room, with a lofty dome; where a large and heterogeneous mass of persons of all nations and classes assemble on public days to buy and sell stock. The design and construction of the dome, by the last named architect, are entitled to the particular notice and admiration of strangers. In the three *per cents.* warrant office, the same profound artist has displayed much taste and skill. It is an oblong room, with a vaulted ceiling springing from ornamented piers; and in the centre is a handsome dome, or lantern light, supported by caryatides. The soffits of the arches are decorated with panels, roses, and other objects in strict conformity to the practice of the ancient architects. It is worthy of remark, that the whole is constructed without timber. Branching from this apartment is another, called the interior office, adapted to clerks whose business is to guard against forgery.

It opens to Lothbury court, which is a grand display of architectural design, two sides of it being formed by open screens, with handsome fluted columns of the Corinthian order. These are copied from the little temple at Tivoli. On the southern side of this court is a noble arch of entrance to the bullion court, and to other offices. This arch and façade are designed after the model of the celebrated triumphant arch of Constantine at Rome. On the sides of the great archway, are four handsome fluted columns, supporting an entablature, and four statues emblematic of the four quarters of the globe. In panels are basso-relievi, executed by that great master of sculpture, Banks, allegorically representing the Thames and Ganges. The chief cashier's office is a noble apartment, in the design of which the architect has again shewn his enthusiastic attachment to classical antiquity. It is in imitation of the temple of the sun and moon at Rome, and is spacious, simple in decoration, and cheerfully lighted by large and lofty windows. In the accomptant's office, governor's court, vestibule and passage from Prince's-street, and recessed portico at the north-western angle, are some specimens of architectural design, which must excite the admiration of every accomplished connoisseur. In all these parts we recognize the forms, style, and detail of the best antique specimens, carefully adapted to their respective situations, and calculated to gratify the eye and satisfy the judgment. Stability is certainly the most essential object in such a building; but beauty and grandeur are equally deserving of attention; for the British bank is rich, its proprietors are presumed to be men of learning and science, and under their auspices we are entitled to look for such actions and such works as shall be ornamental and honourable to the character and taste of the kingdom. In the great enlargements that have been recently made in the present building, it is evident, that the architect has been particularly attentive to the immediate business of the company, the security of their property from fire and depredation, and a chaste, classical style of embellishment. These remarks and descriptions are the result of a recent examination of the building.

Places of Worship.—London is distinguished by the number and variety of its places of worship. It contains 116 churches of the established religion; above 80 chapels of ease on the establishment, in parishes where the population is too great for their respective churches; 11 Roman Catholic chapels; 17 churches and chapels belonging to foreign Protestants; six synagogues of the Jews; and 132 meeting-houses of the different denominations of English Protestant dissenters.

Of the 116 churches above-mentioned, 74 are within the walls of the city, 10 in London, without the walls, nine in the city and liberties of Westminster, five in the borough of Southwark, and 18 in the suburbs, not included in these classes. Of these we can only particularise a few; for descriptions of the whole would require a large volume. Pre-eminent above all the buildings of the metropolis, is the

Cathedral Church of St. Paul, which holds the most distinguished rank among the modern works of architecture in the British empire. The original cathedral was commenced in the year 610, by Ethelbert, king of Kent, and the building, with its revenues and privileges, were greatly increased by succeeding sovereigns. This structure was destroyed by a conflagration in 1086; after which, Maurice, then bishop, commenced the magnificent edifice which immediately preceded the present cathedral. So great was

the magnitude of the building, that neither Maurice, nor his successor De Belmeis, were able to complete the undertaking, though each of them presided twenty years, and expended great sums in the prosecution of it; the latter prelate appropriated the whole revenue of his bishopric to carrying on the work, and supported himself and family by other means. After his death the building was for some time suspended, and the eastern part, or choir, was burnt in the year 1135. At what period it was restored is uncertain; the grand ceremony of consecration was performed in 1240; large additions were afterwards made to the structure, and it was not till the year 1315 that the church was entirely completed; being 225 years from the time of its foundation by Maurice. This ancient cathedral must always be regarded as one of the great works of architecture of the middle ages; in dimensions it far exceeded every other religious edifice in this country; and it is represented by historians as equally pre-eminent in magnificence and splendour of ornament. (For an account of this edifice, see Dugdale's History of St. Paul's.) In the reign of James I., the cathedral having fallen to decay, a royal commission was issued for its repair; but nothing of consequence was done till the advancement of Laud to the see of London, in the succeeding reign. This prelate exerted himself zealously in favour of the neglected building; a subscription was collected to the amount of 101,330*l.* 4*s.* 8*d.*; and Inigo Jones was appointed to superintend the undertaking. He commenced his operations in 1633; and the work went rapidly on till the breaking out of the civil war threw all things into confusion, and the parliament confiscated the unpended money and materials. After the restoration, the repairs were again commenced; but after much labour and expence, the great conflagration in 1666, destroyed the chief part of the building, and irreparably damaged the remainder. Still, however, the magnitude of the work, and the contemplation of the vast expence of building a new cathedral, occasioned a lapse of several years before it was finally determined that all attempts at reparation were hopeless. The impracticability of restoring the ancient church being now apparent, Dr. (afterwards sir) Christopher Wren, was ordered to prepare plans for a new cathedral. The pulling down the remaining walls of the old structure, and the removal of the rubbish to the amount of 47,000 loads, proved excessively laborious as well as dangerous, and several men were killed in the progress of the work. This being completed, the first stone of the new edifice was laid June 21, 1675; and the design was prosecuted with such diligence and success, that within ten years the walls of the choir and side aisles were finished, together with the circular porticoes on the north and south sides. The last or highest stone of the building was laid at the top of the lantern in the year 1710; and shortly afterwards the queen and both houses of parliament attended divine service in the new cathedral. The whole structure was thus completed in thirty-five years, by one architect, sir Christopher Wren, and one master mason, Mr. Thomas Strong, and while one prelate, Dr. Henry Compton, filled the see of London.

The general form or ground plan of St. Paul's cathedral is that of a Latin cross, with an additional arm or transept at the west end, to give breadth to the principal front, and a semicircular projection at the east end for the altar. At the extremities of the principal transept are also semicircular projections for porticoes; and at the angles of the cross are square projections, which, besides containing staircases, vestries, &c. serve as immense buttresses to the dome, which

rises from the intersection of the nave and transept, and is terminated by a lantern, surmounted by a ball and cross of copper gilt. The west front of this fabric consists of a noble portico of two orders, the Corinthian and the Composite, resting on a basement formed by a double flight of steps, of black marble, and surmounted by a spacious pediment. On each side is a tower, with columns, &c.; one serving as a belfrey, the other as the clock-tower. In the tympan of the pediment is a very large piece of sculpture, in basso-relievo, of the conversion of St. Paul; and on the apex a gigantic statue of the same apostle; whilst on either hand, along the summit of the front, are other colossal statues of St. Peter, St. James, and the four evangelists. Large statues of the other apostles are placed upon pediments on the side walls of the fabric. The dome is the most remarkable and magnificent feature of the building. It rises from a circular basement, which, at the height of about twenty feet above the roof of the church, gives place to a Corinthian colonnade, formed by a circular range of thirty columns. Above the colonnade, but not resting upon it, rises an attic story with pilasters and windows, from the entablature of which springs the exterior dome, which is covered with lead, and ribbed at regular intervals. Round the aperture, at its summit, is another gallery; and from the centre rises the stone lantern, which is surrounded with Corinthian columns, and crowned by the ball and cross.

In its interior form, this edifice is entirely constructed on the plan of the ancient cathedrals, *viz.* that of a long cross, having a nave, choir, transepts, and side aisles; but, in place of the lofty tower, the dome in this building rises in elevated grandeur from the central intersection. The architectural detail is in the Roman style, simple and regular. The piers and arches, which divide the nave from the side aisles, are ornamented with columns and pilasters of the Corinthian and Composite orders, and are further adorned with shields, festoons, chaplets, cherubim, &c. The vaulting of this part of the church merits great praise for its light and elegant construction: in this, each severity forms a low dome, supported by four spandrels; the base of the dome being encircled by a rich wreath of artificial foliage. The central area below the dome deserves particular attention: this is an octagon, formed by eight massive piers, with their correlative apertures, four of which, being those that terminate the middle aisles, are forty feet wide, while the others are only twenty-eight; but this disparity only exists as high as the first order of pilasters, at which level the smaller openings are expanded in a peculiar manner, so that the main arches are all equal. The spandrels between the arches above form the area into a circle, which is crowned by a large cantilever cornice, partly supporting by its projection the "whispering gallery." At this level commences the interior tambour of the dome, which consists of a high pedestal and cornice, forming the basement to a range of apparently fluted pilasters of the Composite order, the intervals between which are occupied by twenty-four windows and eight niches: all this part is inclined forward, so as to form the frustum of a cone. Above, from a double plinth, over the cornice of the pilasters, springs the internal dome; the contour being composed of two segments of a circle, which, if not interrupted by the opening beneath the lantern, would have intersected at the apex. The dome, the idea of which was confessedly taken from the pantheon at Rome, is of brick, two bricks thick; but, as it rises, at every five feet has a course of brick, of eighteen inches long, bending through the whole thickness: for greater fe-

curity also, in the girdle of Portland stone which encircles the low part, an enormous double chain of iron, strongly linked together, and weighing nearly 96 *cwt.*, was inserted in a channel, which was afterwards filled up with lead. Over this cupola is a cone of brick, so built as to support a stone lantern of an elegant figure. The choir is of the same form and architectural style as the body of the church.

The dimensions of this vast fabric are, height from the ground without to the top of the cross 340 feet, extreme length within 500 feet, greatest breadth 223 feet. The entire ascent to the ball includes 616 steps. The weight of the ball, which is capacious enough to contain eight persons, is 5600 lbs.; and that of the cross, 3360 lbs. For a more particular description of this edifice, with plan of the substructure, elevation of the west front, section of the dome, and north-east view of the exterior, see "*Fine Arts of the English School*," 4to. 1812.

The particular objects of curiosity which are comprised in this church, and generally shewn to strangers, are the whispering gallery, which encircles the interior of the lower part of the dome, and is so constructed, that a low whisper breathed against the wall, in any part of the circle, may be heard on the opposite side; the library, chiefly remarkable for the floor, which is constructed with small pieces of oak, disposed in geometrical figures; the beautiful model, constructed by sir Christopher Wren; the geometrical staircase, the finest specimen of the kind in Great Britain; the clock, and great bell on which it strikes. The clock is of great magnitude: the length of the minute-hand is eight feet, and its weight 75 lbs.; the hour-hand five feet four inches, and its weight 44 lbs.; the diameter of the dial is eighteen feet ten inches; the length of the hour-figures two feet two inches and a half; the bell is about ten feet in diameter, and its weight nearly four tons and a quarter.

About the year 1790 a scheme was suggested, and has been happily carried into effect, for breaking the monotonous uniformity of the architectural masses in the interior of the cathedral. This was done by admitting large and noble monuments for eminent public persons deceased. These may with strict propriety be termed *national*, as commemorative of British virtues, talents, or heroism. Statues are already erected for Mr. Howard the philanthropist, Dr. Johnson, and sir William Jones. Here are also monuments for generals Abercromby and Dundas, and for captains Mordaunt, Riou, Westcott, Burges, and Faulkner. Others are now erecting for marquis Cornwallis, lord Howe, and lord Nelson. The latter is interred in the vault under the centre of the building; and near him, his friend lord Collingwood. Among other eminent characters who have been deposited in these vaults, are sir Christopher Wren; Dr. Newton, late bishop of Bristol; Alexander Wedderburn, earl of Rosslyn; sir John Braithwaite; sir Joshua Reynolds, president of the Royal Academy; and two other eminent artists, James Barry and John Opie, esqrs.

Although the churches in London are mostly plain, ordinary in architecture, and in obscure situations, yet a few of them are entitled to the notice and admiration of a stranger. That of St. Stephen Walbrooke, built by sir Christopher Wren, is very small, but is justly esteemed for its novelty of design and architectural adornment. "The plan is original, yet simple; the elevation surprising, yet chaste and beautiful; the dome, supported by eight arches, springing from eight single columns, is wonderfully light and scenic in its effect." (*Malton's Picturesque Tour*, p. 76.) Over the altar is a fine picture representing the interment

of St. Stephen, by West. The following churches and towers have claims to architectural beauty, or scientific merit. The tower and spire of Bow-church, in Cleapside, by sir Christopher Wren; the tower of St. Michael's, in Cornhill; the tower and spire of St. Bride's, in Fleet-street; the church of St. Mary, called the New church, in the Strand, by James Gibbs; the church of St. George, in Bloomsbury, by N. Hawksmoor, built in 1731; the tower and spire of St. Dunstan in the East, by sir Christopher Wren; and the church of St. Paul, Covent Garden, by Inigo Jones.

Members of Parliament.—The city of London has no more weight in the legislative representation of the kingdom, than two small boroughs which are the property of an individual. It sends four representatives to parliament, who are chosen, not by the inhabitant householders at large, but by the livery of the several companies. The right of election was anciently vested in the freemen of the city, which gave rise to many contests between the freemen and livery; till an act of parliament, passed in the eleventh year of George I., decided the question, and gave a peremptory right to the livery only. To be possessed of this elective franchise, a man must have previously obtained his freedom of the city, and also of one of the trading companies, either by patrimony, servitude, or purchase; and must afterwards be admitted to the livery of his company. The present number of electors is about eight thousand, which is not above a third part of the number of inhabitant housekeepers. The elections are held in Guildhall, and the sheriffs are the returning officers. The city sent two members to parliament as early as 49 Henry III. The number was increased to four, 6 Edward II.: in that and the succeeding reign, four were frequently sent; but since 43 Edward III., this number has been uniformly returned.

Inns of Court and Chancery.—The design of these establishments having been cursorily noticed under INNS, it may be proper here to subjoin some further particulars relative to each. The inns of court in London are the Inner Temple, the Middle Temple, Lincoln's Inn, and Gray's Inn; but there are several other places called inns, which are appendages to the former. The Temple, belonging to the two societies of the Inner and Middle Temple, is an immense assemblage of buildings, extending from Fleet-street to the Thames; and from Lombard-street, White-friars, to Essex-street in the Strand. It derives its name from a religious house, which was founded by the Knights Templars, who were crusaders; and, in the beginning of the twelfth century, formed themselves into a military body at Jerusalem, for the protection of the pilgrims who visited the holy sepulchre. On the dissolution of the order, the Temple was granted to the Knights Hospitallers of St. John of Jerusalem; and by them it was let for 10*l.* *per annum* to the students of the law, whose successors still possess it. (See HOSPITALERS and TEMPLARS.) The Temple is an irregular building: in Fleet-street are two entrances, one to the Inner and one to the Middle Temple; the latter has a front, in the style of Inigo Jones, of brick, ornamented with four large stone pilasters, of the Ionic order, with a pediment. There are four other entrances; but the gates of all are shut at night. The garden of the Inner Temple is of great extent, and is laid out on the banks of the Thames, with spacious walks, &c. The Middle Temple has also a garden, but small: both are open to the public in summer. The hall of the Middle Temple is a spacious and curious room: the Inner Temple hall, which is smaller, is orna-

mented with the portraits of several of the judges. Each society has a good library for the use of its students. In the treasury chamber of the Middle Temple is preserved a great quantity of ancient armour, which belonged to the Knights Templars. The Temple church belongs in common to both societies, and is open for divine service twice every day. The Knights Templars built a church on this site, which being destroyed, the present edifice was erected by the Knights Hospitallers. It is in the early pointed and late circular styles of architecture, and consists of two distinct parts: at the western end is a spacious round tower or vestibule, forming a grand and singular entrance to the church. In this are the statues of eleven Knights Templars. The organ is esteemed one of the finest in the world. Since the time of Henry VIII. the superior clergyman of this church is called the master of the Temple, and is so constituted by the king's letters patent. For an account of this church, with ground plan and prints, see Britton's *Architectural Antiquities of Great Britain*, vol. i.—Lincoln's Inn is situated on the west side of Chancery-lane. On its site anciently stood a house of the Black-friars, and the palace of the bishops of Chichester. The ground was afterwards granted to Henry Lacy, earl of Lincoln, from whom it derives its name. It appears to have reverted to the bishops; for the present possessors hold it as a grant from a prelate of that see. Lincoln's Inn occupies a very extensive space: the buildings are mostly old and irregular. An attempt has been made, but never completed, to rebuild the Inn on a regular plan. A considerable range, called the Stone Buildings, faces the west. This plan, the work of sir Robert Taylor, is simple and elegant in its exterior architecture; and the chambers are on a grand and commodious scale. In the old part of the building are the hall and chapel; the first of which is a spacious room, in which the lord chancellor holds seals and sittings out of term. At the upper end is a painting by Hogarth, of St. Paul before Felix. The chapel, designed by Inigo Jones, is spacious, and raised on large piers and arches, which form an open area beneath, used as a burial-place for benchers only. The chapel is open for public worship every morning and evening. The garden, which in summer is open to the public, is spacious, and forms one of the finest promenades within the capital. Lincoln's Inn has a good library, which contains a great number of manuscripts; the greater part of which was bequeathed by lord Hale, with a singular injunction, that no part should ever be printed. Gray's Inn is situated on the north side of Holborn, and derives its name from a lord Gray, who resided here. In this Inn is a small neat chapel, a commodious hall, and an extensive garden, with a grove of large elm trees. The inns of chancery, which are dependent on the inns of court, are Furnival's Inn, an appendage to Lincoln's Inn: it is situated on the north side of Holborn-hill, and was the mansion of sir William le Furnival, in the time of Richard II.—Thavies Inn, also dependent on Lincoln's Inn: the old fabric having been recently burnt down, a neat range of buildings is erected on its site, which is near St. Andrew's church, Holborn.—Staple Inn, situated on the south side of Holborn, and an appendage to Gray's Inn: in the hall are casts of the twelve Cæsars, and portraits of Charles II., queen Anne, lord Macclesfield, and the lords chancellors Cowper and Camden.—Barnard's Inn, situated near Fetter-lane, Holborn, and a dependent on Gray's Inn.—Serjeant's Inn, in Chancery-lane: it has a small neat chapel, with seats for the judges.—Clifford's Inn, situated near St. Dunstan's church, Fleet-street, and an appendage to the Inner Temple: in the

hall is an oak case, of very great antiquity.—Clement's Inn, near St. Clement's church in the Strand, a dependent on the Inner Temple: it contains an elegant hall, and a garden kept with particular care, in which is a fun-dial, supported by a kneeling figure of considerable merit, brought from Italy by lord Clare.—New Inn, adjoining to the last mentioned, and an appendage to the Middle Temple.—Lyon's Inn, situated in Wych Street, and belonging to the Inner Temple. For historical and descriptive particulars of these establishments and buildings, the reader is referred to Dugdale's "*Origines Juridicales*," folio, 1680; Herbert's "*Antiquities of the Inns of Court and Chancery*," 8vo. 1804; and Lane's "*Student's Guide to Lincoln's Inn*," 8vo.

General remarks.—Before closing this interesting and important article, it seems proper to offer a very few remarks on the characteristic features of the metropolis, the manners and condition of its inhabitants, and the local peculiarities by which it is distinguished. Such observations, however, the reader will readily perceive must be extremely general indeed. The subject is too various and comprehensive to admit of full development in a section, such as the nature and limits of a work of this kind necessarily prescribe.

The vast extent of London, and its immense population, cannot fail to strike every visitor with wonder and astonishment. Even to those who have previously resided in Paris, or in any other large city, these circumstances alone must be matter of surprise; for not only is this city far more extensive than the imperial metropolis, but it contains at least 400,000 more persons. These, like the inhabitants of all great trading cities, are a heterogeneous mass, composed of foreigners from every town and province of the united kingdoms, with a large portion of Jews, both native and foreign, Indians, Germans, French, Italians, Spaniards, Swifs, and people of almost every nation in the world. From its immense trade, foreign and internal, a constant communication is kept up with every part of the globe, as well as with every part of our own dominions, both at home and abroad. The quantity of property of every description flowing into the metropolis, and distributed from it, is immense. The number of strangers constantly here, either on business or for pleasure, is supposed to be not less than 100,000. Hence the prodigious concourse of people in the streets, and the number of carriages, carts, and other vehicles, continually crowding through them, are unparalleled in any city in the world.

London, in its usual and more extensive application, contains two cities, London and Westminster, besides the borough of Southwark. The city of Westminster was formerly entirely detached from London, for the street now denominated the Strand was, at no very distant period, a sort of bog, or morass, by which they were separated. The monarchs of England have, for several centuries, fixed upon this city as their court residence, and the seat of the legislative and judicial authorities. This portion of modern London and its suburbs have extended with more rapidity than any other district of the town. Its buildings are in a much superior style of architecture, and more open and regular in their distribution and arrangement, than those in the city of London. They are chiefly inhabited by the nobility, gentry, and higher class of merchants, and though perhaps even inferior in external appearance to the residences of the nobles in some other countries, are no where surpassed in internal splendour and magnificence. London, within the walls, is the great repository of the mercantile

wealth, not merely of the metropolis, but of the whole country. Hence the buildings themselves bear ample testimony to the object for which they were raised. Almost every house is a shop, or a counting-house, and so closely are they huddled together, that in many places room is scarcely left for the passage of a single cart. Ground is valuable, and is fully occupied. This renders it certainly a matter of regret, and the remark is applicable to every part of the town, that there exist no regulations, or general plan authorized by act of parliament, to which all builders should be obliged to conform. Such a plan, it is believed, was suggested by Sir Christopher Wren after the great fire in 1666, and since by Gwynn, in a quarto volume, entitled "London and Westminster improved, &c."

In a political point of view, London bears a most important sway in deciding the opinions of the country at large. It is the centre from which all information, civil or military, emanates. The number of newspapers and other political vehicles distributed here, and hence over the united kingdom, is prodigiously great. The foreigner who peruses a few of these, cannot but be astonished at the opposite sentiments they contain, and the freedom with which they praise or censure the measures of government. This is the consequence of liberty, and is doubtless one of its chief supports. The ruling magistrate of the kingdom is not exempt from public censure and critical animadversion. At the commencement of the year 1812, this is more notorious than at any former period; and future historians will have occasion to explain the cause and lament the effect. Not only has London a powerful influence over the political sentiments of the country, but it has likewise no inconsiderable share in directing the conduct of the higher powers. This it effects in some degree by the members it returns to parliament, which are six in number, but much more by the influence and riches of some of its chartered companies, as well as individuals. The bank of England, mostly a body of merchants, is closely identified with government. The minister is compelled to have recourse to the citizens for supplying the deficiencies in the revenue, by loan, all which circumstances render it necessary for the government to pay peculiar attention to the interests of the city in general.

London may further be characterized as the grand theatre for the display of talents either in the arts or sciences. It is here alone, perhaps, of all the cities in the united kingdom, that literary ability will receive any adequate reward. The artist of genius will likewise in general meet here with support and encouragement. He will here find the finest productions of the most celebrated masters in every department of art, by the study of which alone it is possible for him to attain the praise of excellence. In London are to be seen the best actors, and the most splendid theatres, Great Britain can boast of. The talents of the vocal and instrumental performers at the opera and concerts are unrivalled, and probably no city in Europe possesses a place of public amusement more brilliant and magnificent than Vauxhall. London likewise abounds with museums, also various scientific, literary, and rational establishments.

The merchants, bankers, and higher classes of tradesmen, bear a strong resemblance in manners to the gentry with whom, from their immense wealth, they are generally accustomed to associate. The same wealth, and the greater security they possess for its enjoyment than the merchants of other countries, confer upon them a spirit of real indepen-

dence, to which the latter are totally strangers. From this spirit of independence many advantages have undoubtedly arisen both to the political condition and commercial prosperity of England. Reacting as it were upon the springs of our free constitution, from which it proceeds, it tends to render them vigorous and effective. Britons justly boast of their trial by jury as the bulwark of their freedom, but of what use would juries be, if the individuals who compose them were dependent and submissive. It is to the spirit of the people rather than to any particular forms of administration that a country is indebted for its freedom.

The nobility and gentry of London are of a very different complexion from the same classes in other countries. They possess the highest polish of manners, but unite with their accomplishments a degree of manliness and moderation, the result of the freedom of the English constitution and the general diffusion of riches. A foreign nobleman considers himself as a distinct species of being from those who are his inferior in rank and station, and consequently treats them with arrogance and contempt. An English nobleman, on the other hand, while sufficiently conscious of his own superiority, behaves towards those whom fortune has placed beneath him with real attention and civility; even in the article of dress he is scarcely to be distinguished from the ordinary tradesman or mechanic, while the higher class of merchants fully equals him in the splendour of his equipages and establishments. He is almost wholly a stranger to that indolence which usually results from excessive wealth and hereditary titles. Even the ladies of high rank are much less enervated and feeble than most of the same class abroad. They are accustomed to much exercise, and to mix in the public world.

The beneficial operation of this spirit on our commerce is the consequence of that honour and integrity, which are uniformly found to accompany elevation of mind. That honesty is the best policy, has long been an undisputed dogma in commercial transactions in London. Hence it is that an English merchant can often obtain credit even in foreign countries, where it is little practised, and bills of immense value are sometimes entrusted to him without receipt or acknowledgment. But these remarks ought not to be considered as applicable to the higher orders of traders only. The same freedom of conduct and sterling integrity are prominent features in the character of the generality of established shop-keepers, particularly those of the city.

With respect to physicians, surgeons, and barristers, they may be ranked with the gentry, though influenced by some little peculiarity of habits and manners. Apothecaries and attorneys may be classed with the better sort of shop-keepers.

The labouring classes in London are usually of industrious and frugal habits. Their dress and appearance are far more decent and respectable than in any other city in the world, and this alone is a sufficient evidence of its great trade and wealth. The same thing may be said of the poorer sort of shop-keepers, who, from the rate of their earnings, may be placed in the rank of labouring people. Male and female servants, in plain and honest families, may likewise be thrown into this rank with a similar character.

Among many essential improvements recently made in London, the following are worthy of notice and commendation. In the city, and at the east end of the town, we find that new docks have been made on a vast scale, whereby

the property of merchants, companies, and the government is, and will be, materially benefited. Many commodious streets and new houses have also been made in the vicinity of those docks, so that from the Tower to Limehouse a new town has been formed. All the great roads leading to London have been much improved, and every approach to the metropolis, excepting that through the Borough, is broad, good, and flanked by handsome rows of houses, or detached villas. In the city, and immediately adjacent, a wide and handsome street, called Skinner-street, has been entirely new built; a handsome square formed in Moorfields, other streets made near Temple Bar, several new buildings erected around the Bank, and others on Tower-hill. In Mary-le-bone a new plan is executing of laying out a large park into various allotments of detached villas, with gardens and pleasure grounds, by John Nash, esq. architect. The destruction of the two great theatres by fire has afforded opportunities for much improvement, and much has been effected. North of Holborn many new squares and streets have been built, the greater part of which has been designed by James Burton, esq. In subsequent accounts of MARY-LE-BONE, PADDINGTON, and WESTMINSTER, many other subjects will be described.

Publications relating to London and Westminster.—Though many volumes have been expressly devoted to the history and topography of the metropolis, it is generally admitted, and much to be regretted, that not one work is satisfactory either as a comprehensive history, or popular and general description. The most elaborate, and the most complete at the time of publication, is Strype's edition of Stow's "Survey of London," 2 vols. folio, sixth edition, 1754: but this is merely a reprint of a former edition of 1720. As a sort of guide, or popular account of the present metropolis, "The Picture of London for 1812," called "the thirteenth edition," is best adapted to furnish a stranger with a view of London 'as it is': but this, though admirably planned, and well executed in parts, is replete with errors of names, dates, and events. Many of its strictures are objectionable on points of art, taste, and antiquities; and one section on reviews and literary criticism is unjust, and of injurious tendency. The most essential points of these two works, with much additional information, will be comprised in Brayley's "London and Middlesex; or, An historical, commercial, and descriptive Survey of the Metropolis of Great Britain," now in the progress of publication, and promised to be completed in two large octavo volumes. The following are the titles of the other principal works relating to the topography of the metropolis.

"The History of London, from its Foundation by the Romans, to the present Time," by William Maitland, F.R.S. and others, 2 vols. folio, 1765.

"A new and complete History and Survey of the Cities of London and Westminster, the Borough of Southwark, and Parts adjacent," to the year 1770, by Henry Chamberlain, esq. and a society of gentlemen.

"A new History of London, including Westminster and Southwark," by John Noorthouck, citizen and stationer, 4to. 1773.

"Repertorium Ecclesiasticum," by — Newcourt, 2 vols. folio. 1708.

"Londinopolis, or An historical Discourse of the City of London," by Howell, folio, 1657.

"A picturesque Tour through the Cities of London and Westminster," by Thomas Malton, folio, 1792.

"Londinium Redivivum, or An ancient History and modern Description of London," by James Peller Malcolm, F.S.A. 4 vols. 4to. 1807.

"Some Account of London," by Thomas Pennant, esq. 4th edition, 4to. 1805.

"The Customs of London, otherwise called Arnold's Chronicle," new edit. 4to. 1811.

"London; being an accurate History and Description of the British Metropolis, and its Neighbourhood," 6 vols. 8vo. said to be by David Hughson; but really compiled and written by David Pugh. This mode of giving fictitious names is very reprehensible.

"London and Westminster improved, with a Discourse on public Magnificence," by John Gwynn, 4to. 1766.

"A critical Review of the public Buildings, Statues, and Ornaments, in and about London and Westminster," by — Ralph, architect, a new edition, 12mo. 1783.

"A Treatise on the Police of the Metropolis; containing a Detail of the various Crimes and Misdemeanors by which public and private Property and Security are injured; and suggesting Remedies for their Prevention," by P. Colquhoun, L.L.D. 8vo. Several editions have been published.

"A Treatise on the Commerce and Police of the River Thames; containing an historical View of the Trade of the Port of London, and suggesting Means for preventing Depredations thereon, &c. With a Map of the River from London Bridge to Sheerness," by P. Colquhoun, L.L.D. 8vo.

"A Treatise on the Functions and Duties of a Constable; containing interesting Details and Observations, relative to the Corruptions of Morals, and the Protection of the peaceful Subjects against penal Offences," by P. Colquhoun, L.L.D. 8vo.

"The Thames; or, Graphic Illustrations of the Seats, Villas, &c. on the Banks of that River," 2 vols. 8vo. 1811. chiefly a book of prints.

"The History of London and its Environs," 2 vols. 4to. published by John Stockdale.

It appears from Mr. Kirwan's "Estimate of the Temperature of different Latitudes," that from a mean of the observations made at the house of the Royal Society, from the year 1772 to 1780, the annual temperature of London is $51^{\circ}.9$, or in round numbers 52° ; the monthly temperature is stated in the following table:

January	-	35.9	July	-	66.3
February	-	42.3	August	-	65.85
March	-	46.4	September	-	59.63
April	-	49.9	October	-	52.81
May	-	56.61	November	-	44.44
June	-	63.22	December	-	41.04

The greatest usual cold is 20° , and happens in January; the greatest usual heat is 81° , and happens generally in July. The limits of the annual variation are $2^{\circ}.5$, that is, 1° above and $1^{\circ}.5$ below the mean.

The greatest variations of the mean temperature of the same month, in different years, are as follows:

January	-	6	July	-	2
February	-	5	August	-	2
March	-	4	September	-	3.5
April	-	3	October	-	4
May	-	2.5	November	-	4
June	-	2	December	-	3

Hence it appears that the summers differ much less than the winters.

The most usual variations of temperature within the space of 24 hours in every month, are

January	-	6°	July	-	10°
February	-	8	August	-	15
March	-	20	September	-	18
April	-	18	October	-	14
May	-	14	November	-	9
June	-	12	December	-	6

Hence is seen the origin of vernal and autumnal colds.

Mr. Kirwan has shewn that, proportionably to its latitude, it is much colder in London than at Edinburgh; for the mean temperature of Edinburgh in January is $34^{\circ} 5$, and that of London is $35^{\circ} 9$; and this difference he ascribes to the following causes: 1st. That Edinburgh is not exposed to the Siberian winds as London is. 2^{dly}. That Edinburgh is nearer to the sea. 3^{dly}. The rigour of the

northerly winds is very little moderated, if not increased, in passing from Scotland to us, particularly if the surface of the earth is covered with snow; and hence, if we believe Dr. Scrovetter (*Travels to Italy*), the winters are sometimes milder at Edinburgh than at London.

LONDON, a town of America, in Ann-Arundel county, Maryland; 5 miles S.W. of Annapolis.

LONDON, *The township of*, is situated in Upper Canada, on the main fork of the river Thames, is a central position from the lakes Erie, Huron, and Ontario, and offers many advantages for being the capital of the province. It communicates with lake St. Clair and the Detroit by the river Thames; with lake Huron by the northern branch of the Thames and a small portage, and with the Ouse and lake Ontario by the military way called Dundas-street. It abounds with black and white walnut, cherry, bass, elm, hickory, beech, ash, and many other kinds of timber. It is supplied with excellent water, and the situation is healthy.

Looking-glass

LOOKING-GLASS, a plain polished glass speculum, or mirror, to one side of which a plate of tin-foil is made to adhere by means of quicksilver; which being impervious to the light, reflects its rays, and so exhibits the images of objects placed before it.

In consequence of this construction, the looking-glass makes a double reflection of every object, *viz.* one from the upper surface, which is the weakest, and another from the under surface, which is contiguous to the tin-foil. When a person stands just before the glass, the two reflections coincide, and he perceives one image; but if he stands oblique, as at A, (*Plate IX. Optics, fig. 10.*) and views the reflection D, of an object BC, situated on the other side, he will then perceive two images, *viz.* one caused by the upper, and the other caused by the lower surface of the glass EF. If the object BC be very luminous, such as a lighted candle, then the eye at A will perceive a great succession of candles at D, gradually decreasing in splendour; the cause of which phenomenon is, that the strong reflection from the under surface of the glass is again reflected from the upper surface, and this again by the lower, &c.

The theory of looking-glasses, and the laws whereby they give the appearance of bodies, see under **MIRROR**.

LOOKING-GLASSES, the manner of grinding and preparing, is as follows: a plate of glass is fixed to a horizontal table of free-stone or wood, of about the same size, and cemented to it by Paris plaster; and to another lesser table is fixed in the same manner another plate. Over the first plate is sprinkled fine sand and water, in a sufficient quantity for the grinding, and the second or less plate is laid on it; and thus worked this way and that way, till each has planed the other's surface. These plates are made to rub against each other evenly and steadily by a kind of hand-mill, the wheel of which is wrought by a man, or if the plates be large by two men, who regulate the pressure as they think proper. As they begin to become smoother, finer sand is successively used. When one side of the plate is finished, the plaster that cemented it is picked off, and the plate turned, so that the other side may be ground in the same manner. Towards the close of the operation of grinding, the pressure is increased by loading the upper plates with flat stones of

different thicknesses. This process lasts about three days, and it is of great importance that the surfaces should be perfectly flat and parallel, which is determined by the ruler and plumb-line. In order to complete this process, emery of different finenesses is used, and great care is taken in separating and sorting them. This is done by putting into a vessel of water a quantity of rough emery, and well stirring it: the coarsest particles will sink to the bottom, and the finer will be held suspended for some time by the supernatant liquor. This liquor is poured off, and after some time, about 20 minutes, the finer particles will subside. More water is then added to the vessel, and the emery stirred again; and after remaining at rest about 15 minutes, the supernatant liquor is poured off; and this by rest furnishes an emery of the second degree of fineness. The same operation is repeated twice more at the different intervals of about five minutes and half a minute; by which two other sorts are obtained. The wet emery obtained from all these liquors is separably heated over a stove to evaporate the water, and when nearly dry, is made up into balls for the further operation. The plates are then ground on both sides with two or three emerys, beginning with the coarsest, and finished with great care. They are now perfectly even, and the scratches, which after the first operation remained and rendered them almost opaque, disappear. (See **GRINDING**.) For the method of polishing looking-glasses and mirrors, we refer to the article **POLISHING**.

The plates being polished, a thin blotting paper is spread on a table or marble slab; and sprinkled with fine powdered chalk; and this done, over the paper is laid a thin lamina or leaf of tin, on which is poured mercury, which is to be equally distributed over the leaf, with a hare's foot or cotton. Over the leaf is laid a very thin smooth paper, of which the kind called fan-paper is best, and over that the glass plate. With the left hand the glass-plate is pressed down, and with the right the paper is gently drawn out; which done, the plate is covered with a thicker paper, and loaded with a greater weight, that the superfluous mercury may be driven out, and the tin adhere more closely to the glass. When it is dried, the weight is removed, and the looking-glass is complete.

Some use an ounce of mercury with half an ounce of marcasite or bismuth, melted by the fire; and lest the mercury evaporate in smoke, pour it into cold water; and when cold, squeeze it through a cloth or leather. Some also add a quarter of an ounce of lead and tin to the marcasite, that the glass may dry the sooner. For more particular directions in the conduct of this operation, see SILVERING.

In the Phil. Trans. N^o 245, we have a method of *foliating* (see FOLIATING) globe looking-glasses, communicated by sir R. Southwell. The mixture is of quicksilver and bismuth, of each three ounces, and tin and lead, of each half an ounce; to the last throw in the marcasite, and afterwards the quicksilver; stir them well together over the fire; but they must be taken off, and be towards cooling before the quicksilver be put to them. When the mixture is used, the glass should be well heated, and very dry; but it will do also when it is cold, though best when the glass is heated.

Mr. Boyle's method, which he prefers to any which he

ever met with in print, is this: take tin and lead, of each one part, melt them together, and immediately add of good tin-glass, or bismuth, two parts; carefully skim off the dross; then take the crucible from the fire, and before the mixture grows cold, add to it 10 parts of clear quicksilver, and having stirred them well together, keep the fluid in a new clean glass. When you are going to use it, first purge it by straining it through linen, and gently pour some ounces into the glass to be foliated through a narrow paper funnel, reaching almost to the glass, to prevent the liquor from flying to the sides. After this, by dextrously inclining the glass every way, endeavour to fasten it to the internal surface; which done, let it rest for some hours; then repeat the same operation, and so continue at times, till the liquor is slowly passed over, and equally fixed to the whole superficies; which may be discerned by exposing the glass to the eye between that and the light. Boyle's works abr. vol. i. p. 129.

For the method of blowing and casting glass, and the choice of the materials for looking-glasses, see GLASS.

Machine

MACHINE, in a general sense, signifies any thing that is used to augment or to regulate moving forces or powers; or, it is any instrument employed to produce motion, so as to save either time or force. The word is derived from *μηχανή*, *machine*, *invention*, *art*; and is therefore properly applied to any agent in which these are combined, whatever may be the strength or solidity of the materials of which it is composed. The term machine, however, is by common usage generally restricted to a certain class of agents, which seem to hold a middle place between the most simple *organa*, commonly called tools or instruments, and the more complicated and powerful, termed *engines*. This distinction, however, does not enter into the present article; we shall consider machines under two heads, *simple* and *compound*. To the first class belong the *lever*, the *inclined plane*, the *screw*, the *wedge*, the *wheel* and *axle*, and the *pulley*, commonly called the six mechanical powers; though some authors will only allow the lever, and the inclined plane, to be simple machines, the others being compounded of those two.

Compound machines are all such as consist of a combination of the several simple machines or mechanical powers above-mentioned, the number of which in the present advanced state of the sciences is almost infinite. These are again classed under different denominations, according to the agents by which they are put in motion, the purposes they are intended to effect, or the art in which they are employed, as hydraulic, pneumatic, military, architectural, &c. machines. The ancients excelled in the two latter species of engines, but in those which relate to civil arts and manufactory, the moderns have doubtless far exceeded their masters. With regard to military machines, the invention of gunpowder has completely changed their nature, and all those of the ancients are become useless and forgotten; these were principally of three distinct species, *viz.* those employed for throwing destructive weapons; as the *scorpion*, which was for casting arrows; the *catapulta* for stones and javelins; the *pyrobolus* for flaming darts; the *ballista* for bullets, &c. &c.

Others were for razing the walls of fortified places, of which the principal was the *aries*, or *battering ram*; and those of the third kind were for covering the approaches of the besiegers, as the wooden tower, &c.; for a description of which see the respective articles. The warlike machines employed by Archimedes in the defence of Syracuse have been much applauded by the ancients, and though many of the circumstances related on this head are doubtless false or exaggerated, yet it is sufficient to know the genius of their author to be convinced that they were powerful and effective, probably much exceeding any of those of which the construction has been ascertained.

Of the architectural machines of the ancients we are totally unacquainted, and one is at a loss to conceive what means they employed for transporting and raising those enormous stones which are found in the walls of some ancient buildings, though it is not unlikely that they owed as much to their patient perseverance and manual labour, as to the power of their machines. The Spaniards, when they made the conquest of Peru, were struck with astonishment to find the natives, whom they considered as savages and barbarians, raising enormous masses of stone of ten feet square for building walls and other purposes, without the assistance of any instruments than those which nature had supplied them with: unacquainted with any other scaffolding but that of banks of earth raised against their buildings, they contrived by strength of hand to raise these massy loads up the inclined planes thus formed; and many of the Druidical remains in this country were probably erected in a similar manner. The ancient Greek and Roman architects, however, were no doubt acquainted with, and employed very powerful machines in the construction of their noble edifices, with the nature of which we have not been informed; even Vitruvius, who writes expressly on the subject, has left us nothing that can throw any light on the construction of these engines, yet that they were in possession of immense and wonderful machinery, appears in the most convincing manner to any person who reflects on the magnificent structures which they erected, and which excite to this day the wonder and admiration of the world, not only on account of their grandeur and incomparable elegance, but also on account of the mechanical knowledge that seems indispensably necessary for their erection.

The hydraulic machines of the ancients were indeed much inferior to those of modern invention. The *screw* of Archimedes, and the *pumps* of Ctesibius, were the principal engines of this description; for which see the respective articles. As to the modern machines they are too numerous to admit even of a slight enumeration in this place; most of them, however, of any importance, will be found under the several heads in this work. See *CRANES*, *Wind and Water MILLS*, *STEAM Engine*, &c. &c.

Montucla, at the conclusion of the third volume of his "*Histoire des Mathematiques*," has given a catalogue of several interesting works, which have been compiled in order to describe and exhibit the most important and curious machines, both ancient and modern, of which we have selected a few for the information of those who may not possess the above-mentioned work.

1. The first and most interesting modern work of this description is entitled "*Le diverse et artificieuse machine del capitano Agostino Ramelli dal ponte della Trefia*, &c. &c. composte in lingua Italiana et Francese; a Parigi 1588," in folio, (in Germany,) in 1620. This is a very scarce work, seldom to be met with but in choice libraries.

2. "*Machinæ novæ Fausti Verantii cum declaratione*, La-

tina, Italica, Hispanica, Gallica, et Germanica," Venetiis 1591, 1625, in folio, with figures.

3. "*Récueil de plusieurs Machines militaires, &c. pour la Guerre et Récréations*," par François Thypourel et Jean Appus, 1620, 4to.

4. "*Heinrich Zeizings, Theatrum machinarum*," Leipzig 1621.

5. "*A Century of Inventions, &c.*" by Edward Somerset, marquis of Worcester, London 1663, in 12mo.

6. "*Les dix Livres d'Architecture de Vitruve, &c.*" translated into French by Claude Perrault, 1673, folio.

7. "*Veterum mathematicorum, Athenaci, Apollodori, &c.*" 1693, folio. This learned and curious edition of the ancient Greek machinicians was begun by Thevenot, and finished by La Hire; but it relates principally to military engines.

8. "*Theatrum machinarum universale, &c.*" by Jacob Leupold, Leipzig, seven volumes folio, 1724, 1727, 1774. This is the greatest and most complete work of the kind that ever was published. The first volume is little more than an introduction to the work; the second and third volumes contain descriptions of hydraulic machines; the next two volumes relate to machines for raising weights, the theory of levelling, and other subjects; and the sixth treats principally on machines connected with the construction of bridges; the seventh volume is entitled "*Théâtre arithmetico géométrique*," where the author treats of all instruments employed in these two sciences. This work would have been much more considerable, if its author had lived to complete the immense task he had undertaken.

9. "*A short Account of the Methods made use of in laying out the Foundation of the Piers of Westminster Bridge*," by Charles Labelye, 1739.

10. "*The Advancement of Arts, Manufactures, and Commerce; or, A Description of useful Machines and Models*," by A. M. Bailly, London 1778, 1779, folio.

Besides the above-mentioned works, many useful particulars may be gathered from Strada, Besson, Beroaldus, Bockles, Beyer, Lempergh, Van Zyl, Belidor's *Architecture hydraulique*, Defaguliers's *Course of experimental Philosophy*, Emerson's *Mechanics*. The Royal Academy of Sciences at Paris have also given a collection of machines and inventions approved of by them. This work, published by M. Gallon, consists of six volumes in quarto, containing engraved representations of the machines, with their descriptions annexed.

We might have carried the enumeration of works of this kind to a much greater length, but the above are the most interesting, and the reader who wishes for farther information on this subject may consult the history of Montucla above-mentioned. But we ought not to omit to mention in this place, the second volume of the "*Architecture Hydraulique*" of Prony, and the second volume of Gregory's *Mechanics*: the first of these relates principally to steam engines, but the latter contains a description of the most useful modern machines for various purposes.

In the construction of machinery, as also in estimating its effects, several important considerations naturally arise in the mind of a skilful artist, such as the effect of FRICTION, RIGIDITY of ropes, the STRENGTH and STRESS of materials; the proper measure, comparison, and equilibrium of FORCES, the laws of ROTATORY and ACCELERATED motion, &c. &c. These are all treated of under the respective articles in the Cyclopædia, and it therefore only remains for us in this place to offer a few remarks on the nature of machines in general, and the best means of determining their maximum effects.

Machines are introduced for three purposes, viz. to ac-

commodate the direction of the moving force to that of the resistance to be overcome : to increase the effect of a given finite power, so as to overcome a resistance which is greater, and would otherwise ever remain unchanged : and lastly, to regulate and modify a variable force, so as to produce a constant and uniform effect. These are the principal ends to be accomplished by machines, and the experienced engineer will always endeavour to execute them in the simplest manner possible ; for complicated machinery is not only most liable to inaccurate adjustment, and frequent disarrangement, but is likewise more cumbersome and expensive, at the same time that the retardation arising from friction, adhesion, and inertia, is more considerable, and consequently a greater power becomes necessary, in order to produce the same effect. Another important point to be attended to, is the most advantageous application of the first mover, whether this agent be air, water, steam, or animal strength. To enter upon this question in all its generality, would far exceed our limits ; besides, with regard to the three former, they will be better investigated under the articles *Wind* and *Water Mills*, *STEAM Engine*, &c. ; what few remarks, therefore, we have to make on this head, will be confined to the application of animal exertion to the motion of machines, and for the other agents we must refer the reader to the articles above-mentioned.

We have a striking instance of the injudicious application of the exertion of men, in the old crane worked by means of an internal walking wheel, which, from its nature, must be very heavy, while the action of the man is exerted at a very trifling distance from the axle, and consequently at a great mechanical disadvantage ; whereas in Hardie's crane, the man acting externally at the greatest distance from the fulcrum, produces a much greater effect with less expence of labour ; the other advantages which this machine possesses over the one above-mentioned, not arising solely from this cause, are not connected with our present enquiry.

The above remark applies principally to the mechanical advantage to be obtained in the application of a first mover ; but there is also another consideration of a physical nature, which is equally important, and ought therefore to be particularly attended to. No animal can exert more than a determinate and limited force ; and, consequently, if it requires all this force merely to produce an equilibrium, no effect will result from the action ; and, on the other hand, if all the strength of a man or horse is employed in giving motion to himself, or to external objects before the application reaches the resistance, there is still the same unproductive effect. A man, for example, pushing at a capstan bar, must first of all walk as fast as the bar moves round, which evidently requires an expenditure of his muscular power ; but this alone will not render his exertion effective : he must also press the bar forward, with as much force as he has remaining above that which he expended in walking at that rate. The proportion of these two expenditures may be very different under different circumstances ; and on the judicious selection of such circumstances as make the first of these as small as possible, lies much of the skill of the engineer. In the common operation of thrashing corn, much more than half the man's power is expended in giving the necessary motion to his own body ; and only the remainder is employed in urging forward the swingle with a momentum sufficient for shaking out the ripe grains from the stalk. Dr. Robison mentions an experiment, made in order to ascertain the quantity of power thus lost. In order to which, the swingle was taken off the flail, and the same weight of lead put on the end of the staff ; then by causing the labourer to perform the usual motions of thrashing, with all the rapidity

that he could continue during the ordinary hours of work ; it was found that the number of motions thus made was to those made in the actual operation of thrashing, in about the ratio of 3 to 2 : whence we may infer, that at least half the thrasher's power is expended in merely moving his own body. We may also bring another very simple case, by way of further illustration. Suppose a quantity of earth is to be removed from one place to another by barrows. It is obvious that the loads may be so great, that a man must exert his whole strength barely to lift up the shafts, and consequently will have none left to push the barrow forward : if part of the load be taken off, he can go forward, and so much the faster as the quantity of the load is reduced ; but if even the whole be taken away, he can still only move at a certain rate, and, consequently, in neither of the extreme cases is any effect produced. It becomes then an interesting question to determine what load he ought to carry, in order to produce the greatest possible effect in a given time. We shall not, in this place, enter any farther upon this subject, trusting that what has been already advanced will be sufficient to point out the necessity of attending to such circumstances ; and in the subsequent part of the present article, we will endeavour to explain in what manner the proper adjustment of power and effect may be computed.

The nature of the first movement being determined, the next object is to communicate it to the destined point, where the resistance is to be overcome ; and much of an artist's skill depends upon performing this in the simplest and most effectual manner possible. In order to this, it frequently becomes necessary to convert one species of motion into another species : as, for example, a rotatory into a reciprocating motion, or a reciprocating into a rotatory motion, &c. &c. The methods of forming this communication are extremely numerous, and it will not therefore be expected that we should attempt an enumeration of them. In some instances, a simple lever or unbent cord will answer better than any combination ; in others, it is highly advantageous to use a combination of levers acting upon each other by means of so many fulcra, and by which the direction of the motion may be changed at pleasure ; in others, as when motion is communicated to a series of wheels and axles in succession, it may be effected by a rope running in grooves round one wheel and the succeeding axle, or by means of tooth and pinion work, by a barrel and endless screw, and various other contrivances which will naturally suggest themselves, according to the circumstances under which they arise.

This part of the construction being settled, other important circumstances require particular attention, *viz.* to adjust the several parts of the machine so, that its motion may be easy, free, and uniform. One of the most obvious methods of rendering a motion uniform is by means of a *pendulum* and *scapement* (see these two articles) ; and where these cannot conveniently apply, a fly is sometimes employed ; for a particular description of which, see *FLY*. The uniformity of a machine is not, however, wholly dependent upon the application of such regulators : there are other points connected with this subject, that must not be overlooked, and on which we intend to offer a few remarks ; availing ourselves, for this purpose, of the observations of Dr. Robison. When heavy stampers are to be raised, in order to drop on the matters to be pounded, the wipers by which they are lifted should be made of such a form, that the stamper may be raised by a uniform pressure, or with a motion almost perfectly uniform : if this is not attended to, and the wiper is merely a pin sticking out from the axis, the stamper is forced into action at once, which occasions violent

jolts to the machine, and great strains on its moving parts, and their points of support; whereas, when they are gradually lifted, the inequality of the motion is never felt at that point of the machine where the power is applied. We have seen, says the professor, pistons moved by means of a double rack on the piston rod, where a half wheel takes hold of one rack, and raises it to the required height; and the moment the half wheel has quitted that side of the rack, it lays hold of the other side, and forces the piston down again. This was considered as an improvement of the common method of the crank, by correcting the unequable motion of the piston. But in fact it is far inferior to the latter, as it occasions such abrupt changes of motion, that the machine is shaken and torn to pieces with the jolts it occasions; a circumstance which will always be avoided as much as possible by a judicious engineer.

When several stampers, pistons, or other reciprocal movers, are to be raised and depressed, their times of action ought to be distributed in a uniform manner, so that the machine may always be equally loaded with work. When this is done, and the observations in the preceding paragraph attended to, the machine may be made to move almost as smoothly as if there were no reciprocations on it. Nothing shews the ingenuity of the constructor more than the artful, yet simple, contrivances for obviating those difficulties that unavoidably arise from the very nature of the work that must be performed by the machine, and of the power employed. We mentioned, above, the conversion of the continued rotation of an axis into the reciprocating motion of a piston, and the improvement that was thought to have been made in the common and obvious contrivance of the crank, but which, as was observed, occasioned such jolts as would in a short time have destroyed the machine. In order to avoid this, in a large forge where a great sledge hammer of seven hundred weight was to be raised, the engineer formed the wipers into spirals, which communicated motion to the hammer almost without any jolt whatever: and under some circumstances, this contrivance would have been highly beneficial; but in the machine to which we allude, it would not apply, as it did not communicate a sufficient momentum to the hammer in its descent: yet it is deserving of notice, as it might in some cases become extremely advantageous.

In employing a power, which of necessity reciprocates, to drive machinery, in which a rotatory motion is required, as in applying the steam-engine to a cotton or grist-mill, considerable difficulties also arise, which must be attended to with particular care. The necessity of reciprocation on the first mover wastes much power, because the instrument that communicates such immense force must be extremely strong, and well supported. The impelling power is wasted in imparting, and afterwards destroying, a great quantity of motion in the working beam. The skilful engineer will attend to this, and do his utmost to procure the necessary strength of the first mover, without making it a vast load of inert matter: he will also remark that all the strains on it, and on its supports, are changing their direction on every stroke; which therefore requires particular attention in the manner of supporting it. If we observe steam-engines that have been long erected, we shall find that they have uniformly shaken the building to pieces, which is principally to be attributed to the inattention of the engineer to this circumstance; and experience has now taught us, that no building can long withstand the desultory and opposite jolts of such immense masses; and, consequently, that the great movements ought to be supported by a frame-work, independent of the building which contains it. Another cir-

cumstance, on which the uniformity of the motion depends, is the form given to the teeth of the wheel: this is of great importance, and has excited great attention amongst both theoretical and practical machinicians. Two forms have been proposed: of these the first was given by La Hire, who affirmed that the pressure would be uniform, if the teeth were formed into epicycloids; and M. Camus, in his "*Cours de Mathematique*," has adopted and pursued La Hire's principle, and applied it to the various cases that are likely to arise in practice. This construction, however, is liable to a limitation; on which account, a second method has been proposed, which secures the perfect uniformity of motion, without any such limitation. This consists of making both teeth portions of involutes of circles; but as we shall consider this subject under the articles *T-OOTH* and *P-ISTON Work*, it will be useless to insist any farther upon it in this place; and we will therefore proceed to the theoretical investigation of the power of machines, and their maximum effects; limiting our observation to those principally whose motion is uniform, these forming by far the most numerous class, and the knowledge of which is, therefore, of the greatest importance.

Of the maximum Effects of Machines.—When forces acting in contrary directions, or in any such directions as produce contrary effects, there is with respect to every simple machine, and consequently with respect to every compound one, a certain relation between the powers and the distances at which they act, which, if subsisting in any such machine when at rest, will preserve it in that state of statical equilibrium; because the efforts of these powers, when thus related with regard to magnitude and distance, being equal and opposite, destroy each other, and have no tendency to change the state of the system to which they are applied. So also, if the same machine have been put into a state of uniform motion, whether rectilinear or rotatory, by the action of any power distinct from those we are now considering, and these two powers be made to act upon the machine in such motion, in a similar manner to that in which they act upon it when at rest, their simultaneous action will preserve it in that state of uniform motion, or dynamical equilibrium, and this for the same reason as before; because their contrary effects destroy each other, and have, therefore, no tendency to change the state of the machine. But if at the time a machine is in a state of balanced rest, any one of the opposite forces be increased, while it continues to act at the same distance, this excess of force will disturb the statical equilibrium, and produce motion in the machine; and if the same excess of force continues to act in the same manner, it will, like every constant force, produce an accelerated motion; or if it should undergo particular modifications, when the machine is in different positions, it may occasion such variations as will render it alternately accelerated and retarded. Or, the different species of resistance to which a moving machine is subjected, as the rigidity of cords, friction, resistance of the air, &c. may so modify it, as to change a regular or irregular variable motion into one which is uniform. Hence, then, the motion of machines may be considered as of three kinds, as that which is gradually accelerated, which obtains commonly in the first instances of the communication. 2. That which is entirely uniform. 3. That which is alternately accelerated and retarded. Pendulum clocks and machines that are moved by a balance are related to the third class. Most other machines are of the second class, at least a short time after their motion is commenced.

Now, although the motion of a machine be alternately accelerated and retarded, it may, notwithstanding, be mea-

fured by an uniform motion, in consequence of the periodical and regular repetition which may exist in the acceleration and retardation. Thus, the motion of a second pendulum, considered in relation to a single oscillation, is accelerated during the first half second, and retarded during the second; but the same motion taken for many oscillations may be considered as uniform. Suppose, for example, that the extent of each oscillation is five inches, and that the pendulum has made ten oscillations; its total effect will be to have run over 50 inches in 10 seconds, and as the space described in each second is the same, we may compare the effects to a moveable, which moves for 10 seconds at the rate of five inches *per* second. We see, therefore, that the theory of machines, whose motions are uniform, conduces naturally to the estimation of the effects of those whose motion is alternately accelerated and retarded, so that what follows will be directed to those machines only, whose motion falls under the second head, such problems being of far the greatest utility in practice.

We have had already frequent occasion to make use of the terms *mover*, or *moving force* and *resistance*; and in what follows, they will be used in the same general sense. By the first is always to be understood any cause of motion whatever, and by the latter, any thing that is opposed to the action of the former. The *impelled point* of a machine, is that to which the action of the moving power may be considered as immediately applied; and the *working point* is that where the resistance arising from the work to be performed immediately acts, or to which it ought all to be reduced. Thus in the wheel and axle, *Plate I. fig. 6. Mechanis.*, where the moving power *P* is to overcome the weight or resistance *W*, by the application of the cord to the wheel and to the axle, *A* is the impelled point, and *E* the working point. The *velocity of the moving power* is the same as the velocity of the impelled point; and the *velocity of the resistance*, the same as that of the working point. The *performance* or *effect* of a machine, or the *work done*, is measured by the product of the resistance into the velocity of the working point; and the *momentum of impulse* is measured by the product of the moving force into the velocity of the impelled point.

These definitions being established, we may exhibit a few of the most useful problems relative to the effect of machines, and with which we must conclude this article.

Let *A B* (*Plate XXXII. Mechanis.*, *fig. 1.*) represent the velocity of a stream, *A C* the velocity of the part of the engine which it strikes, when the motion of the machine becomes uniform, and *C B* will represent their relative velocity, upon which the effect of the engine depends. It is known that the action of a fluid upon a given plane, is as the square of this relative velocity; consequently the weight raised by the engine, when its motion becomes uniform, being equal to this action, it is likewise as the square of *C B*. Let this be multiplied by *A C*, the velocity of the part of the engine, impelled by the fluid; and the effect of the engine in a given time will be proportional to $A C \times C B^2$ (supposing *C B* to be bisected in *D*) $A C \times 2 C D \times 2 D B = 4 A C \times C D \times D B$; consequently, the effect of the engine is greatest when the product of *A C*, *C D*, and *D B* is greatest. But it is easy to see, that this product is greatest when the parts *A C*, *C D*, and *D B*, are equal; for if you describe a semicircle upon *A D*, and the perpendicular *C E* meet the circle in *E*, then $A C \times C D = C E^2$, and is greatest when *C* is the centre of the circle; so that in order that $A D \times C D \times D B$ may be the greatest possible, *A D* must be bisected in *C*; and *C B* having been bisected in *D*, it follows

that *A C*, *C D*, *D B*, must be equal; or that *A C*, the velocity of the part of the engine impelled by the stream, ought to be but one-third of *A B*, the velocity of the stream. In this case, when, (abstracting from friction) the engine acts with the utmost advantage; the weight raised by it is to the weight that would just sustain the force of the stream, as the square of *C B*, the relative velocity of the engine and stream, to the square of *A B*, which would be the relative velocity, if the engine was quiescent; that is, as 2×2 to 3×3 , or 4 to 9. Therefore, that the engine may have the greatest effect possible, it ought to be loaded with no more than $\frac{4}{9}$ ths of the weight, which is just able to sustain the efforts of the stream. See Maclaurin's Account of sir Isaac Newton's Discoveries, p. 171, and Fluxions, art. 908.

Again, suppose that a given weight *P*, (*fig. 2.*) descending by its gravity in the vertical line, raises a greater weight *W*, likewise given, by the rope *P M W*, (that passes over the fixed pulley *M*) along the inclined plane *B D*, the height of which *B A* is given; and let it be required to find the position of this plane, along which *W* will be raised in the least time, from the horizontal line *A D* to *B*. Let *B C* be the plane upon which, if *W* was placed, it would be exactly sustained by *P*; in which case, *P* is to *W* as *A B* to *B C*. But *W* is to the force with which it tends to descend along the plane *B D*, as *B D* to *A B*; consequently the weight *P* is to that force, as *B D* to *B C*. Therefore the excess of *P* above that force (which excess is the power that accelerates the motion of *P* and *W*) is to *P*, as *B D - B C* to *B D*; or taking *B H* upon *B C* equal to *B D*, as *C H* to *B D*. But it is known that the spaces described by motions uniformly accelerated, are in the compound ratio of the forces which produce them and the squares of the times; or, that the square of the time is directly as the space described in that time, and inversely as the force; consequently, the square of the time in which *B D* is described by *W*, will be directly as *B D*, and inversely as $\frac{C H}{B D}$, and will be least when $\frac{B D^2}{C H}$ is a minimum; that is, when $\frac{B C^2}{C H} + C H + 2 B C$, or (because

$2 B C$ is invariable) when $\frac{B C^2}{C H} + C H$, is a minimum.

Now as when the sum of two quantities is given, their product is a maximum when they are equal to each other; so it is manifest, that, when their product is given, their sum must be a minimum when they are equal. Thus it is evident, that as in *fig. 1*, the rectangle or product of the equal parts *A C* and *C D* was equal to *C E*²; so the rectangle of any two unequal parts, into which *A D* may be divided, is less than *C E*, and *A D* is the least sum of any two quantities, the product of which is equal to *C E*². But

the product of $\frac{B C^2}{C H}$ and *C H* is $B C^2$, and consequently

given: therefore the sum of $\frac{B C^2}{C H}$ and *C H* is least when

these parts are equal, that is, when *C H* is equal to *B C*, or *B D* equal to $2 B C$. It appears, therefore, that when the power *P* and weight *W* are given, and *W* is to be raised by an inclined plane, from the level of a given point *A* to the given point *B* in the least time possible; we are first to find the plane *B C*, upon which *W* would be sustained by *P*, and to take the plane *B D* double in length of the plane *B C*; or we are to make use of the plane *B D*, upon which

a weight that is double of W could be sustained by the power P .

For another example; suppose a fluid, moving with the velocity and direction AC , (*fig. 3.*) strike the plane CE ; and suppose that this plane moves parallel to itself in the direction CB , perpendicular to CA , or that it cannot move in any other direction. Then let it be required to find the most advantageous position of the plane CE , that it may receive the greatest impulse from the action of the fluid. Let AP be perpendicular to CE in P , draw AK parallel to CB , and let PK be perpendicular upon it in K , and AK will measure the force with which any particle of the fluid impels the plane EC , in the direction CB . For the force of any such particle being represented by AC , let this force be resolved into AQ , parallel to EC , and AP perpendicular to it; and it is manifest, that the latter AP only has any effect upon the plane CE . Let this force AP be resolved into the force AL perpendicular to CB , and the force AK parallel to it; then it is manifest, that the former, AL , has no effect in promoting the motion of the plane in the direction CB ; so that the latter AK , only, measures the effort by which the particle promotes the motion of the plane CE in the direction CB . Let EM and EN be perpendicular to CA and CB , in M and N ; and the number of particles, moving with directions parallel to AC , incident upon the plane CE , will be as EM . Therefore the effort of the fluid upon CE being as the force of each particle, and the number of particles together, it will be as $AK \times EM$; or, because AK is to AP ($= EM$) as EN to CE , as $\frac{ME^2 \times EN}{CE}$;

so that CE being given, the problem is reduced to this, to find when $EM^2 \times EN$ is the greatest possible, or a maximum. But because the sum of EM^2 and of EN^2 ($= CM^2$) is given, being always equal to CE^2 , it follows that $EN^2 \times EM^2$ is greatest when $EN^2 = \frac{1}{2} CE^2$; in the same manner as it was demonstrated above, that when the sum of AC and CB (*fig. 1.*) was given, $AC \times CB$ was greatest, when $AC = \frac{1}{2} AB$. But when $EN^2 \times EM^2$ is greatest, its square root $EN \times EM$ is of necessity at the same time greatest. Therefore the action of the fluid upon the plane CE , in the direction CB , is greatest when $EN^2 = \frac{1}{2} CE^2$, and consequently $EM = \frac{1}{2} CE$; that is, when EM , the sine of the angle ACE , in which the stream strikes the plane, is to the radius, as the $\sqrt{2}$ to $\sqrt{3}$; in which case it easily appears, from the trigonometrical tables, that this angle is of $54^\circ 44'$.

Several useful problems in mechanics may be resolved by what was shewn in the preceding paragraph. If we represent the velocity of the wind by AC , a section of the sail of a windmill, perpendicular to its length by CE , as it follows from the nature of the engine, that its axis ought to be turned directly towards the wind, and the sail can only move in a direction perpendicular to the axis, it appears, that when the motion begins, the wind will have the greatest effect to produce this motion, when the angle ACE , in which the wind strikes the sail, is of $54^\circ 44'$. In the same manner, if CB represent the direction of the motion of a ship, or the position of her keel, abstracting from her lee-way, and AC be the direction of the wind, perpendicular to her way, then the most advantageous position of the sail CE , to promote her motion in the direction CB , is when the angle ACE , in which the wind strikes the sail, is of $54^\circ 44'$. The best position of the rudder, where it may have the greatest effect in turning

round the ship, is determined in like manner, and the same angle enters likewise into the determination of the figure of the rhombuses that form the bases of the cells in which the bees deposit their honey in the most frugal manner. (See *HONEY-Comb.*) But it is to be carefully observed, that when the sine of the angle ACE is to the radius as $\sqrt{2}$ to $\sqrt{3}$; or, which is the same thing, when its tangent is to the radius as the diagonal of a square to its side; this is the most advantageous angle only at the beginning of the motion of the engine; so that the sails of a common windmill ought to be so situated, that the wind may indeed strike them in a greater angle than that of $54^\circ 44'$. For it is demonstrable, that when any part of the engine has acquired the velocity c , the effort of the wind upon that part will be greatest, when the tangent of the angle in which the wind strikes it, is to the radius, not as the

$\sqrt{2}$ to 1, but $\sqrt{2} \times \frac{9c^2}{4a^2} \times \frac{3c}{2a}$ to 1, the velocity of the wind being represented by a . If, for example, $c = \frac{1}{2}a$; then the tangent of the angle ACE ought to be double of the radius; that is, the angle ACE ought to be of $63^\circ 26'$. If $c = a$; then ACE ought to be of $74^\circ 19'$. This observation is of the more importance, because, in this engine, the velocity of the parts of the sail remote from the axis bears a considerable proportion to the velocity of the wind, and perhaps sometimes is equal to it; and because a learned author, Daniel Bernouilli, has drawn an opposite conclusion from his computations in his hydrodynamics, by mistaking a minimum for a maximum; where he infers, that the angle in which the wind strikes the sail, ought to decrease as the distance from the axis of motion increases; that if $c = a$, the wind ought to strike in an angle of 45° ; and that if the sail be in one plane, it ought to be inclined to the wind, at a medium, in an angle of 50° . How he fell into these mistakes, is shewn by Maclaurin, in his Fluxions, § 914.

In like manner, though the angle ACE of $54^\circ 44'$ be the most advantageous at the beginning of the motion, when a ship sails with a side wind; yet it ought to be enlarged afterwards as the motion increases. In general, let Aa (*fig. 3.*) parallel to CB , be to AC , as the velocity which the engine has already acquired in the direction CB , to that of the stream; upon AC produced, take AD to AC as 4 to 3, draw DG parallel to CB , and let a circle described from the centre C with the radius Ca , meet DG in g ; and the plane CE shall be in the most advantageous situation for promoting the motion of the engine, when it bisects the angle ACg .

It is generally supposed, that a direct wind always promotes the motion of a ship, the sail being perpendicular to the wind, more than any side-wind; and this has been affirmed in several late ingenious treatises; but, to prevent mistakes, we are obliged to observe, that Maclaurin has demonstrated the contrary in his Treatise of Fluxions, § 919; where other instances of this second general problem in mechanics are given, to which we refer. See Maclaurin's Account of Sir Isaac Newton's Philosophical Discoveries, book ii. chap. 3. p. 173.

Let ϕ denote the absolute effort of any moving force, when it has no velocity, and suppose it not capable of any effort when the velocity is W ; let F be the effort answering to the velocity V , then if the force be uniform, we shall have

$$= \phi \left(1 - \frac{V}{W} \right)$$

For it is the difference between the velocities W and V which is efficient, and the action, being constant, will vary as the square of the efficient velocity. Hence we shall have this analogy,

$$\phi : F :: (W - v)^2 : (W - V)^2,$$

and, consequently,

$$F = \phi \left(\frac{W - V}{W} \right)^2 = \phi \left(1 - \frac{V}{W} \right)^2 \quad \text{Q.E.D.}$$

Although the pressure of an animal is not actually uniform during the whole time of its action, yet it is nearly so, and therefore in general we may adopt this hypothesis, in order to approximate to the true nature of animal action. On which supposition the preceding proposition, as well as the following one, will apply to animal exertion. By retaining the same notation, we have also

$$W = \frac{V \sqrt{\phi}}{\sqrt{\phi} - \sqrt{F}},$$

which formula, applied to the motion of animals, gives the following theorem.

The utmost velocity with which an animal, unimpeded, can move, is to the velocity with which it moves when impeded with a given resistance; as the square root of its absolute force to the difference of the square roots of its absolute and efficient forces.

Again, to investigate expressions by means of which the maximum effect, in machines whose motion is uniform, may be determined.

1. It follows from the observations made in the preceding part of this article, that when a machine, whether simple or compound, is put into motion, the velocities of the impelled and working points are inversely as the forces which are in equilibrio when applied to those points in the direction of their motion. Consequently, if f denotes the resistance when reduced to the working point, and v its velocity; while F denotes the force acting at the impelled point, and V its velocity, we shall have $FV = fv$, or introducing t , the time, $FVt = fv t$. Hence

In all working machines which have acquired an uniform motion, the performance of the machine is equal to the momentum of the impulse.

2. Let F be the effort of a force upon the impelled point of a machine, when it moves with a velocity V , the velocity being W , when $F = 0$, and let the relative velocity $W - V = u$.

Then, since $F = \phi \left(\frac{W - V}{W} \right)^2$, by the foregoing proposition, the momentum of impulse FV becomes

$$FV = V \phi \left(\frac{u}{W} \right)^2 = \phi \frac{u^2}{W^2} (W - u);$$

because, since $W - V = u$, we have $V = W - u$.

Now making this expression for FV a maximum, or supposing the constant quantities, and making

$$u^2 (W - u) = \text{a maximum},$$

we have, by throwing it into fluxions,

$$2u \dot{u} W - 3u^2 \dot{u} = 0, \text{ or } 2W = 3u, \text{ or } u = \frac{2}{3}W;$$

whence, again, $V = W - u = W - \frac{2}{3}W = \frac{1}{3}W$.

Consequently, when the ratio of V to v is given by the construction of the machine; and the resistance is susceptible of variation, we ought to load the machine more or less, till the velocity of the impelled point is one-third of the greatest

velocity of the force, in order that the work done may be a maximum.

Or the work done by an animal is the greatest when the velocity with which it moves, is one-third of the greatest velocity with which it is capable of moving when not impeded.

Again, since we have

$$F = \phi \frac{W^2}{W^2} = \phi \frac{4}{9} \frac{W^2}{W^2} = \frac{4}{9} \phi,$$

in the case of the maximum, we have also

$$FV = \frac{4}{9} \phi V = \frac{4}{9} \phi \cdot \frac{1}{3} W = \frac{4}{27} \phi W,$$

for the momentum of impulse, or for the work done when the machine is in the best state.

Consequently, when the resistance is a given quantity, we must make

$$V : v :: 9f : 4\phi,$$

which structure of the machine will give the maximum effect $= \frac{4}{27} \phi W$.

If we enquire the greatest effect on the supposition that ϕ only is variable, we must make it infinite in the above expression for the work done, which would then become

$$WF, \text{ or } W \frac{V}{v} f, \text{ or } W \frac{V}{v} f t,$$

including the time in the formula.

Whence we come to this important conclusion, viz.

That the sum of the agents employed to move a machine may be infinite, while the effect is finite.

For the variations of ϕ , which are proportional to this sum, do not influence the above expression for the effect. The last theorem may be applied to the action of men and of horses, with more accuracy than might at first be supposed. Observations have been made on men and horses drawing a lighter along a canal, and working several days together. The force exerted was measured by the curvature and weight of the track rope, and afterwards by a spring steel-yard. The product of the force thus ascertained into the velocity per hour, was considered as the momentum; and in this way the action of the men was found to be very nearly as $(W - V)^2$. The action of the horses, loaded so as not to be able to trot, was nearly as $(W - V)^2$, or as $(W - V)^2$. Hence the hypothesis above adopted may, in many cases, be safely assumed. According to the best observations, the force of a man at rest is on an average about seventy pounds, and the utmost velocity with which he can walk is about six feet per second, taken at a medium. Hence in the above theorems $\phi = 70$, and $W = 6$; consequently $F = \frac{4}{9} \phi = 31\frac{1}{3}$ lbs., the greatest force a man can exert when in motion, and he will then move at the rate of $\frac{1}{3} W$, or two feet per second, or rather less than $\frac{1}{4}$ mile per hour.

The strength of a horse is generally reckoned about six times that of a man, that is, about 420 lbs. at a dead pull. His utmost walking velocity is about ten feet per second; and therefore his maximum action will be $\frac{4}{9} \times 420 = 186\frac{2}{3}$ lbs. and he will then move at the rate of $\frac{1}{3}$ of 10, or $3\frac{1}{3}$ feet per second, or nearly $2\frac{1}{4}$ miles per hour. In both these instances we suppose the force to be exerted in drawing a weight, by a cord running over a pulley, which makes its direction horizontal.

The theorem above given may serve to shew under what points of view machines ought to be considered by those who would labour beneficially for their improvement. The first object of utility is in furnishing the means of giving

to the moving force the most commodious direction, and when it can be done of causing its action to be applied immediately to the body to be moved. These, it is true, can rarely be united, but the former may, in most instances, be accomplished; of which the use of the simple lever, pulley and wheel and axle, furnish many examples. The second object gained by the use of machines, is an accommodation of the velocity of the work to be performed, to the velocity with which alone a natural power can act. Thus, whenever the working power acts with a certain velocity, which cannot be changed, and the work must be performed with a greater velocity, a machine is interposed round a fixed support, and the distance of the impelled and working points are taken in the proportion of the two given velocities. But the essential advantage of machines, and that in fact which properly appertains to the theory of mechanics, consists in augmenting, or rather modifying the energy of the moving power, in such a manner that it may produce effects, of which it would otherwise have been incapable. Thus a man might carry up a flight of steps twenty pieces of stone, each weighing say 30lbs. one by one, in as small a time as he could, with the same labour, raise them all together with a piece of machinery, that would have the velocities of the impelled and working points as twenty to one, and in this case the instrument would furnish no real advantage except in saving his steps. But if a large block of 20 times 30, or 600lbs, were to be raised to the same height, it would far exceed his utmost efforts to accomplish it, without the intervention of some machine. Or the same purpose may be illustrated somewhat differently, confining the attention still to those machines whose motion is uniform. The product $f v$ represents, during the unit of time, the effect which results from the motion of the resistance; this motion being produced in any manner whatever. If it be produced by applying the moving force immediately to the resistance, it is necessary, not only that the product $F V = f v$, but also at the same time $F = f$ and $V = v$; if, therefore, as most frequently happens, f be greater than F , it will be absolutely impossible to put the resistance in motion, by applying the moving power immediately to it. Now, machines furnish the means of disposing of the product $F V$ in such a manner, that it may always be equal to $f v$, however much the factors $F V$ may differ from the analogous factors in $f v$; and consequently of putting the system in motion, whatever may be the excess of f above F . Or, generally, as Prony remarks, (Arch. Hydraul. art. 501.) machines enable us to dispose of the factors $F V$ in such a manner, that while that product continues the same, its factors may have to each other any ratio at pleasure. Thus, to give another example: suppose that a man, exerting his strength immediately upon a mass of 25lbs. can raise it vertically, with the velocity of four feet per second; the same man acting upon a mass of 1000lbs. cannot give it any vertical motion, though he exerts his utmost strength, unless he has recourse to some machine. Now he is capable of producing an effect equal to $25 \times 4 \times t$; the letter t being introduced, because, if the labour be continued, the value of t will not be indefinite, but comprised within assignable limits. Thus we have $25 \times 4 \times t = 1000 \times v \times t$; and, consequently, $v = \frac{1}{10}$ th of a foot. This man may, therefore, with a machine as a lever, or axis in *peritrochia*, cause a mass of 1000lbs. to rise $\frac{1}{10}$ th of a foot in the same time that he could raise 25lbs. 4 feet without a machine; or he may raise the greater weight as far as the less, by employing forty times as much time. From what has now been said on the extent of the effects which may be attained by machines, it will be seen, that so long as a moving force exercises a determinate

effort with a velocity likewise determinate, or so long as the product of these is constant, the effects of the machine will remain the same: so that under this point of view, supposing the preponderance of the effort of the moving power, and abstracting from inertia and friction of materials, the convenience of application, &c., all machines are equally perfect. But from what has been shewn in the preceding part of this article, a moving force may, by diminishing its velocity, augment its effort, and reciprocally. There is, therefore, a certain effort of the moving force, such that its product by the velocity, which comports to that effort, is the greatest possible. Now admitting of the truth of the results in the preceding propositions $V = \frac{1}{4} W$, or $F = \frac{3}{4} \phi$, and these two values obtaining together their product, $\frac{3}{4} \phi W$ expresses the value of the greatest effect with respect to the unit of time; and in practice it will always be advisable to approach as nearly to these values as circumstances will admit, for it cannot be expected that it can always be exactly attained. But a small variation will not be of much consequence; for by a well known property of those quantities, which admit of a proper maximum or minimum, a value assumed at a moderate distance from either of these extremes, will produce no sensible change in the effect.

If the relation of F to V followed any other law than that which we have assumed, we should find from the expression of that law, values of F and V , &c. different from the preceding, but the general method would be still nearly the same.

With respect to practice, the grand object in all cases should be to procure an uniform motion, because it is from that which, *ceteris paribus*, the greatest effect, always results. Every irregularity in the motion waits some of the impelling power, and it is the greatest only of the varying velocities which is equal to that, which it would acquire if it moved uniformly throughout; for while the motion accelerates, the impelling power is greater than what balances the resistance at that time opposed to it, and the velocity is less than what the machine would acquire, if moving uniformly; and when the machine attains its greatest velocity, it attains it because the power is not then acting against the whole resistance. In both these cases, therefore, the performance of the machine is less than if the power and the resistance were exactly balanced, in which case it would move uniformly. Besides this, when the motion of a machine, and particularly a very ponderous one, is irregular, there are, as we have already remarked in the preceding part of this article, continual repetitions of strains and jolts, which soon derange, and ultimately destroy the whole structure.

In the preceding remarks and propositions, relative to the maximum effect of machines, we have availed ourselves of an interesting chapter on this subject in Gregory's Mechanics, in which the theory is pursued to a much greater length than our limits will admit of, both with regard to machines whose motions are uniform and accelerated; and to which we would refer the reader for further information. See also Prony's "Architecture Hydraulique," from art. 487 to 507; and the last edition of Ferguson's Mechanics by Brewster, in which an interesting paper on this subject is given by professor Leslie.

MACHINE for taking down extemporaneous pieces of music, commonly called *voluntaries*. Such a contrivance has been long among musical *desiderata* of the most important kind. To fix such floating sounds as are generated in the extatic moments of enthusiasm, while "bright-eyed fancy

"Scatters from her pictured urn,
Thoughts that breathe, and notes that burn,"

would be giving permanence to ideas which reflection can never find, nor memory retain.

The first idea of such a contrivance being practicable was suggested to the Royal Society of London, in a paper written by the late Rev. Mr. Creed, and sent to the president, 1747, under the following title :

"A demonstration of the possibility of making a machine that shall write *extempore voluntaries*, or other pieces of music, as fast as any master shall be able to play them, upon an organ, harpsichord, &c. and that in a character more natural and intelligible, and more expressive of all the varieties those instruments are capable of exhibiting, than the character now in use."

This paper was published the same year in the Philosophical Transactions, N^o 183, and, afterwards, in Martyn's Abridgment, vol. x. p. 266; and the author's idea always appeared to us so feasible, that we have long wondered at its not having been executed by some ingenious English mechanic.

The first mention that we can find to have been made at Berlin, of such a contrivance, was in 1752, in a printed "Weekly Account of the most remarkable Discoveries in Nature and Science." In 1753, an ample description of such a machine appeared in the same weekly publication: and here, in an elaborate preface, the author points out the great want of such a piece of mechanism, its utility, and properties; and concludes with saying, that this machine, so big with advantages to music and musicians, is the *particular invention, Besondere Erfindung*, of M. Unger.

The description preceded the execution some time. The invention was here only recommended to the public, and offered to be completed, and applied to a keyed instrument, at a small expence. It was M. Hohlfeld who afterwards constructed the machine, and rendered it so perfect, that we were assured by a great performer, who tried it upon a clavichord, that there was no refinement in music which it could not express, except *tempo rubato*.

The description of the Berlin machine so much resembles that proposed by Mr. Creed, that we shall not insert it here, but refer our readers to the Philosophical Transactions, where he will find that the machine was to consist of two cylinders, which were to be moved by clockwork, at the rate of an inch in a second of time; one of these was to furnish paper, and the other was to receive it when marked by pins or pencils, fixed at the ends of the several keys of the instrument to which the machine was applied. The paper was to be previously prepared with red lines, which were to fall under their respective pencils.

The chief difficulties in the execution, which have occurred to English mechanics, with whom we have conversed on the subject, were, the preparation of the paper for receiving the marks made by the keys; and the kind of instrument which was to serve as a pencil, and which, if hard and pointed, would, in the *forte* parts, tear the paper; and if soft, would not only be liable to break when used with violence, but would be worn unequally, and want frequent cutting.

In the Berlin machine the pencils were approximated according to Mr. Creed's idea, and made to terminate in a very narrow compass, so that paper of an uncommon size was not requisite; but it was not found necessary to prepare the paper, as proposed in the Philosophical Transactions; for the degree of gravity or acuteness of each sound was ascer-

tained by a ruler applied to the marked paper, when taken off the cylinder.

About the year 1780, the late ingenious and marvellous mechanic Merlin, stimulated by the reports of this machine having been successfully constructed in Germany, and by our earnest recommendation of the undertaking, went to work, and apparently vanquished all the difficulties of construction, except the time inevitably necessary for its completion; as he was never able to simplify the mechanism so much as to render its appropriation within the reach of great composers and voluntary players in general, to whose use only it seems to belong; he disposed of his model to a foreign nobleman, who had it conveyed to Germany, and we believe never fabricated another machine of the same kind. See MERLIN.

MACHINE, in *Dramatic Poetry*, is when the poet brings some divinity or supernatural being upon the stage; to perform some exploit, or solve some difficulty, out of the reach of human power.

The machines of the drama are gods, angels, ghosts, &c. They are so called from the machines or contrivances by which they are represented upon the stage, and afterwards removed again.

Hence the use of the word machine has also passed into the epic poem; though the reason of its name be there wanting. It denotes, in both cases, the intervention or ministry of some divinity; but as the occasion of machines in the one and the other is somewhat different, the rules and laws of managing them are different likewise.

The ancient dramatic poets never brought any machine on the stage, but where there was an absolute necessity for the presence of a god; and they were generally laughed at for suffering themselves to be reduced to such a necessity. Accordingly, Aristotle lays it down as an express law, that the unravelling of the piece should arise from the fable itself, and not from any foreign machine, as in the *Medea*. Horace is somewhat less severe, and contents himself with saying, that the gods should never appear, unless where the *nodus*, or knot, is worthy of their presence; "*Nec deus interfit, nisi dignus vindice nodus—inciderit.*" But it is quite otherwise with the epopea; in that there must be machines every where, and in every part. Homer and Virgil do nothing without them. Petronius, with his usual fire, maintains, that the poet should deal more with the gods than with men; that he should every where leave marks of his prophetic raptures, and of the divine fury that possesses him; that his thoughts should be all full of fables, that is, of allegories and figures: in fine, he will have a poem distinguished from a history in all its parts; not so much by the verses, as by that poetical fury, which expresses itself wholly by allegories; and does nothing but by machines, or the ministry of the gods. A poet, therefore, must leave it to the historian to say, that a fleet was dispersed by a storm, and driven to foreign shores; and must himself say, with Virgil, that Juno went to seek Æolus; and that this god, at her request, turned the winds loose against the Trojans: he must leave the historian to write, that a young prince behaved with a great deal of prudence and discretion on all occasions; and must say, with Homer, that Minerva led him by the hand in all his enterprizes: let an historian say, that Agamemnon, quarrelling with Achilles, hath a mind to shew him, though mistakenly, that he can take Troy without his assistance; the poet must say, that Thetis, piqued at the affront her son had received, flies up to heaven, there to demand vengeance of Jupiter: and that this god, to satisfy her, sends the god Somnus, or Sleep, to Agamemnon,

to deceive him, and make him believe that he shall take Troy that day.

It is thus that the epic poets used machines in all parts of their works; in the *Iliad*, *Odyssey*, and *Æneid*, the proposition mentions them; the invocation is addressed to them; and the narration is full of them: they are the causes of actions; they make the knots, and at last they unravel them. This last circumstance is what Aristotle forbids in the drama; but it is what Homer and Virgil have both practised in the epopea. Thus Minerva fights for Ulysses against Penelope's lovers; helps him to destroy them; and, the next day, herself makes the peace between Ulysses and the Ithacans; which closes the *Odyssey*. The use of machines in the epic poem is, on some accounts, entirely opposite to what Horace prescribes for the theatre. In tragedy, that critic will never have them used without an absolute necessity; whereas, in the epopea, they should never be used, but where they may be as well let alone; and where the action appears as if it did not necessarily require them. How many gods and machines does Virgil implore to raise the storm that drives *Æneas* into Carthage; which yet might easily have happened in the ordinary course of nature.

In Milton's *Paradise Lost*, most of the actors are supernatural personages; and in Voltaire's *Henriade*, the poet has made excellent use of St. Louis.

Machines, in the epic poem, therefore, are not contrivances of the poet, to recover himself after he has made a false step, nor to solve any difficulty peculiar to some part of the poem; but it is the presence of a divinity, and some supernatural and extraordinary action, which the poet inserts in most of the incidents of his work, to render it more majestic and admirable, and to train up his readers to piety and virtue. This mixture should always be so managed, as that the machines may be retrenched, without retrenching any thing from the action. As to the manner in which the machines are to act; it may be observed, that in the old mythology, there are gods both good, bad, and indifferent; and that our passions may be converted into so many allegorical divinities: so that every thing, both good and bad in a poem, may be attributed to these machines, and may be transacted by them. They do not, however, always act in the same manner; sometimes they act without appearing, and by simple inspirations, which have nothing in them extraordinary or miraculous; as when we say, the devil suggested such a thought, &c. The second manner of acting is entirely miraculous; as when a divinity presents itself visible before men, so as to be known by them; or when they disguise themselves under some human form without discovering themselves. The third manner partakes of each of the two, and consists in oracles, dreams, and extraordinary inspirations: all which Bossu calls *semi-machines*.

All these manners ought to be so managed as to carry a verisimilitude: and though verisimilitude be of a vast extent in machines, as being founded on the divine power, yet it has its bounds. See farther, on the importance and use of machinery, the article *EPIC POEM*.

MACHINE, in *Agriculture*, a term applied to instruments of various kinds which are contrived either for the purpose of lessening labour or performing the different operations and processes of the art with greater accuracy and correctness, such as those of sowing, drilling, reaping, threshing, winnowing, and a great many others. The term is most commonly employed when the nature of the tool is of the more complex kind. It may, however, be employed with propriety in many other circumstances. See *THRASHING MACHINE*.

MACHINE, *Architectonical*, is an assemblage of pieces of wood so disposed, as that, by means of ropes and pulleys, a small number of men may raise vast loads, and lay them in their places. Such are cranes, &c.

It is hard to conceive what sort of machines the ancients must have used to raise those immense stones found in some of the antique buildings. See MACHINE, *supra*.

MACHINE, *Blowing*. See BELLOWS, and BLOWING MACHINE.

MACHINE, *Bruising*, a contrivance for the purpose of crushing and reducing grain, pulse, malt, and other articles, some of which are employed as team food. Machines of this kind are made in London by Rowntree and others.

MACHINE, *Chaff-cutting*, a tool contrived for the purpose of cutting straw, hay, and other similar materials into chaff for the purpose of food for team-horses, and other animals. There are various descriptions of this kind of machinery which act on very different principles, and some of them have lately undergone very much improvement. See CHAFF-CUTTER.

MACHINE, *Draught*, a simple contrivance formed for the purpose of ascertaining the force or power of draught, in drawing ploughs, and various other implements where draught is required. A machine of this sort, invented by Mr. More, late secretary to the Society for the Encouragement of Arts, &c. in London, is thus described by Mr. Young in the first volume of the *Annals of Agriculture*. It is a spring coiled within a cylindrical case, having a dial-plate, marked with numbers like that of a clock, and so contrived that a hand moves with the motion of the spring, and points to the numbers in proportion as the force is exerted: for instance, when the draught equals 1 cwt. over a pulley, the hand points to *fig. 1*; when the draught is equal to 2 cwt. it points to *fig. 2*; and so on. Till this very useful machine was invented, Mr. Young says, it was exceedingly difficult to compare the draught of different ploughs, as there was no rule to judge but by the exertions of the horses as apparent to the eye; a very indefinite mode of ascertaining their force.

MACHINE, *Drill*, that sort of tool which is employed in sowing and depositing various kinds of grain, pulse, and small seeds, in drills or rows. They are very differently formed, according to the purposes for which they are intended, and the manner of drilling which is intended to be practised.

They require to be constructed with great correctness, and in as simple a manner as possible, in order that they may perform their work with accuracy, both in respect to the drills, the quantity of seed, and the depth of depositing it in the soil.

In the choice of this sort of machinery, the farmer should be principally directed by the nature and extent of his land, the situation which it possesses, and the kinds of crops which he intends to cultivate. They have lately been so contrived, as, by slight alterations in the sowing parts, to be capable of not only sowing grain as well as small seeds, but of executing the work at different distances, and in a greater or less number of rows at once, as circumstances may require.

There are several machines of this nature, which perform the business in a very exact and regular manner; among which are Cook's, Bailey's, Amos's, M'Dougall's, and many others; each of which sow several rows at the same time, and some of them are likewise capable of forming horse-hoes.

Besides these, there are also drills constructed for parti-

cular sorts of crops, as those of peas, beans, turnips, &c. See *Plough Drill*, and *Turnip Drill*.

A drill machine, invented by Mr. Robert Salmon of Woburn, Bedfordshire, which obtained the premium given by the duke of Bedford, at Woburn sheep-shearing, a few years ago, for the best newly-invented agricultural implement, is described below. This machine drills and sows at the same time; and the principal improvement in it, as in Cook's drill, and others, consists in constructing it in such a manner, that the workman who holds the drill has a perfect command upon it, with respect to the direction in which it shall move, even though the horse which draws it should deviate from the line the drill is intended to follow. In *Plate (Machines) Agriculture*, is given a descriptive representation of the machine, in which *fig. 1* is a section of a part, *fig. 2* an elevation of the same, *fig. 4* is a perspective view of the whole, and *figs. 3* and *5* detached parts.

The great wheels, A, A, *fig. 4*, have their axle-trees attached to the bed B, to which are framed the long handles, D, D, forming a frame independent of the remainder of the machine, and having no connection with it, except in the middle of the bed B, where a short beam, E, is jointed to it, as is well explained in *fig. 1*; the other end of this beam is mortised into a cross beam F, to which the three drills, G, G, G, are fixed; a frame formed of two horizontal pieces, H, H, *fig. 2* and *4*, and four vertical pieces, I, I, I, I, is erected upon F; the handles, D, D, pass between H, H, but are not fixed thereto; the hook a, by which the machine is drawn, is fixed to the two middle uprights, I, I, and a strong chain leads to the harness of the horse employed; K is the seed-box supported from H, H, by two uprights for the purpose; the box is a frustum of a pyramid, and joins at the bottom to a prismatic box, containing the seed-roller b, *fig. 1*, which is exactly the same length as the box, and comes through its ends, its pivots being supported by a piece of iron-plate fixed at the end of the box, as seen in *fig. 4*; a brush, d, presses upon the roller, and is adjustable by a screw that it may always bear upon it with an equal degree of force; a number of notches is cut in the circumference of the roller, and as the box K is full of seed, it always rests upon the roller; when it turns round, it takes one of the notches full of seed, and passing it by that means under the end of the brush d, delivers it into a tin-plate tube r, which conveys it down into the furrow made by the drill; the roller has three series of notches answering to the three drills G, G, G; at e, a piece of leather presses against the roller, to prevent any seed getting down, except that which passes under the brush d; f is a slider, which stops the seed from coming down to the roller, when shoved in, and is used when the machine is required to advance without sowing, or when a lesser number of rows is required to be sown. The roller is turned by means of an endless chain, q q, passing round a groove made in the middle of the roller, from thence it proceeds through a block of pulleys at t, shewn separate in *fig. 5*, to a small wheel b; the block, t, is made of cast-iron, and slides freely up and down between the two innermost uprights, I, I, of the frame; its weight keeps the chain always tight, and prevents it from slipping without turning the roller; the wheel, b, is fixed upon an axle p, on the end of which is a cog-wheel, turned by another cog-wheel on the nave of the great wheel A; these wheels are enclosed in a box k, which likewise contains a contrivance for disengaging the wheels, shewn on a larger scale in *fig. 3*, where p is a section of the axle p, passing through a long staple fixed to the bed B; it can slide up and down in this staple, except when confined by a catch o, pressed against it by a spring. In the present

position, the cog-wheels are engaged to work together: but by pulling the cords m and l, the former draws back the catch o; and the other, by means of the crooked lever n n, raises up the axle p, and disengages the cog-wheels; the return of the catch, o, prevents its descent; the cords, l and m, are conducted to the end of the handles, D, D where they are both attached to one handle, in reach of the workman who guides the machine.

The operation of the drill is exceedingly simple. As the horse draws it along by means of the chain, the drills, G, G, G, make the furrows, and the seed-roller delivers the seed in small quantities, and at regular intervals into them. As the hook a, from which the chain draws, is placed nearly in the centre of the machine, it will easily be made to follow any other line than that in which the horse draws, by turning the handles, D, D, to one or other side. This alters the direction of the wheels, A, A, which immediately proceed in that line, and the drill follows them. This quality is of the greatest consequence in making straight work. L is a cross piece fixed to the handles, D, D, and supporting a handle M, by which, and one of D, the workman holds when he guides the drill, as he is then in a position to see the drills made last, and adapt the present ones to them; the wheel always going in the last made drill. Another handle, similar to M, is fixed to the other end of L, to be used when the machine is on the other side of the work done last. The drills are fixed to the piece F by screws, and their distance from one another can be altered at pleasure. The seed-box containing the roller is made in two halves, connected by hooks, so that it can be taken apart, and the roller removed for a fresh one to be put in with different sized notches, for sowing a different kind of grain.

The drawing was taken from a machine made by Mr. Shepherd, Woburn, and exhibited at Woburn sheep-shearing, June 1808. Mr. Salmon has made a great number of the same pattern, which are now in use, and are found to answer well. Several of them have five drills instead of three, and are in that case worked by one horse.

In this drill, at whatever distance the shares are placed to go from each other, the distance from the wheels to the two outside rows is always equal thereto; consequently, when at work, one or the other of the wheels always runs in the last made drill, thereby gauging accurately the interval between each bout the drill goes; and as the holder always goes in the line of the wheel, he can distinctly see and correct the smallest error that may have been made in any previous bout.

In all cases, one horse is sufficient to draw this drill either for three or more rows, as little depends on the horse's inclination; and a driver can be dispensed with, where tractable horses are used. As in all machines of this sort, in proportion to the number and distance of rows made, so will be the quantity of work performed.

MACHINE, *Electrical*. See *ELECTRICAL Machine*.

MACHINE, *Fan*, in *Agriculture*, a common name applied to that sort of tool which is employed in removing the chaff from the grain. See *WINNOWER Machine*.

MACHINE, *Land-Levelling*, the name of an useful machine, invented by Mr. David Charles, for the purpose of rendering high ridges and other inequalities, in such lands as are in a state more level and even in their surfaces. It would seem probable that no effective implement of this sort has hitherto been introduced. But such a machine is said, in "Transactions of the Society of Arts," to be useful and necessary even in the most fertile parts of the country, where the improved system of drill-husbandry has

MACHINE

been introduced, or even where there is any attention to the waste of time, or to the ease of cattle in the act of ploughing; in order to get rid of crooked or unequal ridges, without either a summer fallow by cross ploughing, or else by frequent repetitions of ploughing in the winter and spring, which the humidity of this climate will not allow in every kind of soil. "Fourteen acres of land were reduced with this tool by the inventor to a perfect level, where the crowns of the ridges were about two feet higher than the furrows, and where they were crooked and of unequal breadths. But the chief success has been upon a field of eight acres, which lay in an unprofitable state, and which is a deep clay, that had produced a crop of wheat from an old lay sod the former year, without any manure, which was winter ploughed, and lay in that state until the machine was introduced the first dry weather in April. It was preceded by two horse ploughs, taking perhaps a square of an acre at once: these loosened the soil the depth of a common furrow, and twice the breadth across the ridges. The levelling machine followed, drawn by two oxen and two horses, with a man at each handle, to press it down where the height was to be removed, and to lift up the body by the handles where it was to be discharged. Thus, four men, one driver, and eight head of cattle, will more effectually level from half an acre to three roods in one day, according as the earth is light or heavy, than sixty or eighty men would accomplish with harrows and shovels, &c. even with the assistance of a plough. In sandy ground, where the depth of one furrow will bring all to a level, as much, of course, will be done in one day as two ploughs can cover;" but in this case, the ground required to be gone over several times. It is further stated, that "after this field was levelled, the backs of the ridges, as they are termed, which were stripped of their vegetable mould, were ploughed up, the furrows not requiring it. They were also harrowed, and the field copiously manured with lime-compost, harrowed in, and broke into nine feet ridges, perfectly straight, in order to introduce Duckitt's drill. It was sown under furrow, broad-cast, the last of it not until the 13th of May, and was cut down a reasonable crop the 4th of September." And "the field now lies in proper form, well manured, with the advantage of a fair crop from heavy tenacious ground, without losing a season, and in a year by no means favourable." The writer is "well aware there are many shallow soils, where it may be hazardous to remove the enriched surface, and trust perhaps one half of the land for a crop that had never before been exposed to the atmosphere; but where the soil is sufficiently deep, or there is a good under-stratum, with manure at hand to correct what is lost for want of exposure and tillage, it is evident, from this experiment, that no risk is run." And in order "to avoid the expense of a fallow, and to lay out ground in straight and even ridges, even where drill husbandry is not practised, should be objects to every rational farmer: but where the new system is intended to be adopted, it becomes indispensably necessary. In laying down lawns, parks, &c. where furrows are an eye-sore, or places inaccessible to wheel-carriages from their declivity, and from which earth is to be removed, it will also be found equally useful." Besides these, there are many other cases in which the old rounded ridges may be levelled down with great advantage, either by this or some other means.

A representation of this machine is given at *fig. 1. in Plate (Machines) Agriculture*, in which *a*, *fig. 2.* is a part of the pole, to which the oxen or horses which draw the machine are fastened, and which is attached to the machine by a pin at *b*; *c, c,* the two wheels, shod with iron, which run upon the axle *d*; *e, e,*

the upper frame work of the machine, extending from the axle to the extremity of the handles, *f, f,* and secured firmly by the cross pieces, *g, g,* the curved iron sliders of the machine, which may be raised or depressed a little by means of the pins, *h, h,* which pass through holes in the wood-work, and also in the iron sliders. These sliders form one piece with the back iron scraper *i*, in the manner more fully explained in *fig. 3. k,* the wooden back of the machine, which should be made strong, to resist the weight of the earth when collected therein. The iron scraper should be firmly secured to this by screws and iron work; *l, l,* the wooden sides of the machine, firmly connected with the back and frame work, in order to assist in collecting the earth to be removed; *m*, a strong cross piece, into which the ribs which support the back are well mortised.

The interior part of the back of the machine is shewn at *k*, in *fig. 3*: *i*, the iron scraper, sharp at the bottom, firmly screwed to the back of the machine; *g, g,* parts of the side irons or sliders, shewing the mode in which they are united with the scraper *i*; *m*, the cross piece already described.

MACHINES, Military, among the *Ancients*, were of three kinds: the first serving to launch arrows, as the scorpion; or javelins, as the catapulta; or stones, as the balista; or fiery darts, as the pyrobolus: the second serving to beat down walls, as the battering ram and terebra: and the third to shelter those who approach the enemies wall, as the tortoise or testudo, the vinea, pluteus, and the towers of wood. These machines, together with their proportions and properties, are described in the works of Vitruvius, Ammianus Marcellinus, and other writers. Mr. Grose has given descriptions and drawings of these in the *first* volume of his "Military Antiquities," chap. xii.

MACHINE, Stone-lifting, in *Agriculture*, an implement of the triangle kind, similar to that used by wood-cutters for weighing bark, constructed for the purpose of raising large stones of some tons weight used in the northern parts of Scotland, and many other places. It is supposed to save much expence in powder and boring as well as labour, three men being sufficient to work it. It is described in the *Agricultural Survey of Perthshire* in this manner

"The three legs, *a, d, b, d,* and *c, d,* which are shewn at *fig. 4*, are beams of any hard wood, four inches thick, six inches broad, and about fourteen feet long. Their thinnest side points inwards, which gives them more strength. Their feet form on the ground an equilateral triangle *abc*, and their three tops at *d* are fixed together by an iron rod, which passes through each. The two legs *a, d* and *b, d* are fixed to one another by the windlafs *k*, and by the cross-bar *o, p, q*. There are two pullies *e* and *f*, with an iron hook two inches in circumference to each; *g, g, g* may be (more than one, but rather) one iron chain which goes round the stone *n*, while lying in the ground at *m*, below its greatest diameter, or where it begins to become narrow. This chain consists of rounded links, which are about three inches long, and about the thickness of a man's little finger. It has a hook at one end, that may be put into any link towards the other end, which will make it embrace the stone exactly, and be of the same circumference, where the stone touches the earth; *h, g, b, g, h, g*, are shorter chains of the same workmanship, whose hooks are fixed into links of the surrounding chain at *g, g, g*, and so on round the stone, having the corresponding link of each fixed on the hook of the lower pulley at *b*. The whole rope must be of the same thickness with the two great hooks, two inches in circumference.

"All things being thus prepared, two men turn round the handles of the cylinder, and the waggoner assisting them

by applying a lever to any side of the stone that seems to be firmest, they force it aloft, and hold it up at the proper height, until the driver put his carriage backward between *b* and *c*, which carriage ought to have a strong frame upon four low stout wheels; then the stone is let gently down and carried away."

By this sort of machine large stones or other bodies can be raised and removed without any great difficulty.

MACHINE, Threshing, a contrivance made use of instead of the flail for threshing corn and other seed crops. See *THRESHING Machine*.

MACHINE, Water, or Hydraulic, is either used to signify a simple machine, serving to conduct or raise water; as a sluice, pump, &c. or several of these acting together, to produce some extraordinary effect; as the

MACHINE of Marli. See *MARLI*. See also *FIRE-engine*, *STEAM-engine*, and *WATER-works*.

MACHINE, Water-raising, a sort of machine contrived for the purpose of raising water a few feet high by the power of the *wind*, for the purpose of draining morasses, or of watering lands on a higher level, and other similar uses. A section of it is given in *fig. 5*, and it is described by the author of the *Philosophy of Agriculture and Gardening* to "consist of a windmill sail placed horizontally, like that of a smoke-jack, surrounded by an octagon tower; the diverging rays of this tower, *a b, a b*, may consist of two-inch deals only, if on a small scale, or of brick-work if on a larger one. These upright pillars are connected together by oblique horizontal boards at *A B*, by which boards placed horizontally from pillar to pillar in respect to their length, but at an angle of about 45 degrees in respect to their breadth, so as to form a complete octagon, including the horizontal windmill sail near the top of it; the wind, as it strikes against any of them, from whatever quarter it comes, is bent upwards, and then strikes against the horizontal wind-sail. These horizontal boards, which form the sides of the octagon, may either be fixed in their situations, or be made to turn upon an axis a little below their centres of gravity, so as to close themselves on that side of the octagon tower most distant from the wind. It may be supposed that the wind thus reflected, would lose considerably of its power before it strikes on the wind-sail; on fixing a model of such a machine, however, on the arm of a long whirling lever, with proper machinery to count the revolutions of the wind-sail, when thus included in a tower, and moving horizontally; and then when moved vertically, as it was whirled on the arm of the lever with the same velocity, it was found on many trials by Mr. Edgeworth, in Ireland, and Dr. Darwin, at Derby, that the wind, by being thus reverted upwards by a fixed planed board, did not seem to lose any of its power. And as the height of the tower may be made twice as great as the diameter of the sail, there is reason to conclude, the doctor thinks, that the power of the horizontal wind-sail may be considerably greater, than if the sail was placed nearly vertically opposed to the wind in the usual manner. At the bottom of the shaft of the wind-sail is placed a centrifugal pump with two arms at *D, C*, which consists simply of an upright bored trunk, or cylinder of lead, with two opposite arms with an adapted valve at the bottom to prevent the return of the water, and a valve at the extremity of each arm to prevent any ingress of air above the current of the water as it flows out; *cccc* is a circular trough to receive the streams of water from *C* and *D*, to convey them where required in any particular operation or process.

And at *fig. 6* is another machine, invented by Mr. Sergeant, of Whitehaven, calculated for raising or forcing

water in particular cases, as for domestic or other uses. It is extremely simple and cheap in its construction, the whole, exclusive of the pump pipes, &c. not costing more than five pounds. The object for which it was particularly contrived was that of raising water for the supply of a gentleman's house from a stream running at the distance of about 140 yards. In which intention a dam was made a little distance above, so as to cause a fall of about four feet, the water being brought by a wooden trough, into which was inserted a piece of two-inch leaden pipe, a part of which is seen at *a*, in the figure; the stream of this pipe is so directed as to run into the bucket *b c*, when the bucket is elevated; but as soon as it begins to descend, the stream flows over it, and goes to supply the wooden trough, or well, in which the foot of the forcing pump, *c*, stands, of three inches bore; *d* is an iron cylinder attached to the pump rod, which passes through it, which is filled with lead, and is in weight about 240 pounds. This is the power which works the pump, forcing the water through 240 feet of inch pipe from the pump up to the house. At *e* a cord is fixed, which, when the bucket comes to within four or five inches of its lowest projection, becomes stretched, and opens a valve at the bottom of it, through which the water discharges itself. This sort of pump may be found very beneficial in a variety of instances where its application can be admitted.

MACHINE, Wind. See *ANEMOMETER*, and *WIND Machine*.

MACHINERY, in the Lyric theatre, or Opera-house. In the early operas of Italy, during the 17th century, it seldom happened that the names of the poets, composers, or singers, were recorded in printed copies of the words; though that of the machinist was seldom omitted; and much greater care seems to have been taken to amuse the eye than the ear or intellect of those who attended these spectacles.

In 1675, we are told, in the *Theatrical Annals of Venice*, that a musical drama, called *La Divisione del Mondo*, written by Giulio Cesare Corradi, and set by Legrenzi, excited universal admiration, by the stupendous machinery and decorations with which it was exhibited. And in 1680, the opera of *Berenice*, set by Domenico Freschi, was performed at Padua in a manner so splendid, that some of the decorations recorded in the printed copy of the piece seem worthy of notice in this article. The musical drama consisted of poetry, music, dancing, machinery, and decorations; and it would be curious to point out the encroachments which any one of these constituent parts at different periods has made upon the rest. In the beginning it was certainly the intention of opera legislators to favour Poetry, and make her mistress of the feast; and it was a long while before Music absolutely took the lead. Dancing only slept into importance during the last century; but very early in the 17th century, machinery and decorations were so important, that little thought or expence was bestowed on poetry, music, or dancing, provided some means could be devised of exciting astonishment in the spectators, by splendid scenes and ingenious mechanical contrivances.

In the opera of *Berenice* just mentioned, there were choruses of one hundred virgins, one hundred soldiers, one hundred horsemen in iron armour, forty cornets of horse, six trumpeters on horseback, six drummers, six ensigns, six sacbuts, six great flutes, six minstrels playing on Turkish instruments, six others on octave flutes, six pages, three serjeants, six cymbalists, twelve huntsmen, twelve grooms, six coachmen for the triumph, six others for the procession, two lions led by two Turks, two elephants by two others, *Berenice's* triumphal car drawn by four horses, six other cars with prisoners and spoils drawn by twelve horses, six

coaches for the procession. Among the scenes and representations in the first act, was a vast plain, with two triumphal arches; another, with pavilions and tents; a square prepared for the entrance of the triumph; and a forest for the chase. Act II. the royal apartments of Berenice's temple of vengeance; a spacious court, with a view of the prison; and a covered way for the coaches to move in procession. Act III. the royal dressing room, completely furnished; stables with one hundred live horses; portico adorned with tapestry; a delicious palace in perspective. And besides all these attendants and decorations, at the end of the first act, there were representations of every species of chase: as of the wild boar, the stag, deer, and bears; and at the end of the third act, an enormous globe descends from the sky, which opening divides itself into other globes that are suspended in the air, upon one of which is the figure of Time, on a second that of Fame, on others, Honour, Nobility, Virtue, and Glory. Had the salaries of fingers been at this time equal to the present, the support of such expensive and puerile toys, would have inclined the managers to enquire, not after the best, but the cheapest vocal performers they could find; as splendid ballets often oblige them to do now; and it is certain, that during the 17th century, the distinctive characteristic charm of an opera was not the music, but machinery. The French established musical dramas in their court and capital during the rage for mythological representations, to which they have constantly adhered ever since; and when they are obliged to allow the musical composition and singing to be inferior to that of Italy, they comfort themselves and humble their adversaries by observing, that their opera is, at least, a fine thing to see: "c'est au moins un beau spectacle, qu'un opera en France."

MACHINERY, in *Mechanics*, may be considered as the operative and moving parts of machines; it is, however, very generally, though perhaps improperly, applied to include all the parts of machines, fixed as well as moving, and in this view may be considered as the instruments or parts by which the principles of mechanics are carried into execution, and rendered applicable to all the purposes of arts and manufactures.

The denomination machine is now vulgarly given to a great variety of subjects that have very little analogy by which they can be classed with propriety under one name: we say a travelling machine, a bathing machine, a copying machine, a threshing machine, an electrical machine, &c. &c. The only circumstances in which all these agree, seem to be, that their construction is more complex and artificial than the utensils, tools, or instruments which offer themselves to the first thoughts of uncultivated people; they are more artificial than the common cart, the bathing tub, the flail, or the glass tube which first discovered the phenomena of electricity. In the language of ancient Athens and Rome, the term was applied to every tool by which hard labour of any kind was performed; but in the language of modern Europe, it seems restricted either to such tools or instruments as are employed for executing some philosophical purpose, or of which the construction employs the simple mechanical powers in a conspicuous manner, so that their operation and energy engage the attention. It is nearly synonymous, in our language, with *engine*; a term altogether modern, and in some measure honourable, being bestowed only, or chiefly, on contrivances for executing work in which ingenuity and mechanical skill are manifest. Either of these terms, machine or engine, is applied with impropriety to contrivances in which some piece of work is not executing on materials, which are then said to be manufactured. A *travelling* or *bathing* machine is surely a vulgarity.

A machine or engine is, therefore, a tool, but of complicated construction, peculiarly fitted for expediting labour, or for performing it according to certain invariable principles: and we should add, that the dependence of its efficacy or mechanical principles must be apparent, and even conspicuous.

The contrivance and erection of such works constitute the profession of the engineer; a profession which ought by no means to be confounded with that of the mechanic, the artisan, or manufacturer. It is one of the *Artes liberales*; as deserving of the title as medicine, surgery, architecture, painting, or sculpture. Nay, whether we consider the importance of it to this flourishing nation, or the science that is necessary for giving eminence to the professor, it is very doubtful whether it should not take place of the three last named, and go *pari passu* with surgery and medicine.

In the language of our practical mechanics, the terms *machine*, *engine*, and *mill*, are used without a proper distinction of the classes of machinery to which they should in strictness be applied. All these denominations are alike the practical applications of the science of mechanics, and consist only of different combinations of the mechanical powers. Though the combinations and modifications which the ingenuity of mankind is constantly producing are endless, still it is possible, by a proper classification, to arrange them under their proper terms, to avoid the confusion which at present prevails amongst those of our ingenious countrymen, who have laboured to improve the arts dependent on mechanics, without troubling themselves to fix upon the most precise language in which to express their ideas. If we might presume to decide upon a proper definition of these words, which has not hitherto been done, we should advise that the term machine be used as generic, and applied to any mill, engine, instrument, or apparatus having moving parts. That machinery should also be used as a general term, signifying the moving and operative parts of any machine or engine whatever, and its synonymous term mechanism be applied to the most delicate machinery, such as the parts of watches and mathematical instruments, or to the most delicate parts of any other machine, as the machinery of a flour-mill, or sawing-mill; the mechanism of a clock, watch, orrery, &c.

Let the term *engine* be restricted to such machines as have some relation to hydraulics or pneumatics, or, in short, where their operations depend upon, or actuate fluids; as a steam engine, a water engine, pumping engine, blowing engine, pressure engine, and fire extinguishing engine.

Mill should be applied to large and powerful compound machines, or systems of machines; including their first mover in the term; as a cotton mill, which contains a vast number of different machines, and also the water wheel, or steam engine, which actuates them all; so likewise, an iron mill, copper mill, rolling mill, grinding mill, logwood mill, worsted mill, &c. &c.

Corn mill, or *flour mill*, is, in some degree, an exception to our definition, because in the early stages of society it was the only mill in use, and hence the term became particularly attached to it; and any machine for grinding or reducing to powder is called a mill, as a coffee mill, bark mill, colour mill, malt mill, &c. though, in strictness, these should be called machines.

In this classification, we have studied to infringe as little as possible upon the distinctions which have been made by custom, and confirmed by the usage of mechanics themselves, though not invariably, for they have dividing engines, cutting engines, and many others which should be machines.

The practical application of mechanics to the construction of machinery, is a subject of the utmost importance to the welfare of our country, depending so materially as it does upon commerce, which is derived chiefly from our manufactures; and these owe the pre-eminence they have over other nations to the general introduction of machinery, which has taken place within these forty years, to abridge manual labour in every department, and in every trifling operation: it is to this source we must look for the increase of property of every description, as the introduction of every machine is a real creation of all the work it will perform, without the addition of farther increase of human labour. An idea is very generally entertained, that machinery is prejudicial to the interest of mankind, as far as it tends to diminish the value of that labour by which the lower classes of society can alone purchase the means of subsistence: this idea is, however, founded on error, as applied to any supposed injury society in general can sustain, though individuals whose labours are superseded by machines, will suffer inconvenience for a time, yet it is only for a time, and so long as they, or others more intelligent, shall discover a new channel for the exertion of their industry. As machines tend to increase the quantities of those luxuries and necessities of life which mankind are so anxious to obtain, it only requires that an equitable division of these benefits should be made to obviate every objection, and really improve the condition of all classes; a retrospect of the last forty years shews the truth of this observation, for though so many machines have been employed in all trades and manufactures as probably to do more work than the whole population could do previous to that period, yet the value of human labour has, notwithstanding, increased in the same proportion as other articles have advanced in price.

We shall, in this article, enter into some general observations upon the construction of machinery, and particularly point out such contrivances as seem applicable to other purposes than those for which their inventors have employed them; and we shall give, as examples of practical machinery, a description of the famous block machines at Portsmouth, which contain many new contrivances. We were unable to introduce these under the article *Block*, as the machines were not erected at the time that article was printed.

The grand object of all mechanism, or machinery, is to convey and modify the motion of the first mover of the machine, and communicate it in a proper manner to the subject to be operated upon: thus, the slow rotative motion of a water-wheel is, by the machinery of cranks, levers, and toothed wheels, converted into a rapid reciprocating motion for working sawing machines, and the velocity of the motion is increased or diminished, as the occasion requires either great power or great speed. In like manner, the rectilinear motion of the piston rod of a steam engine is, by the machinery of parallel levers, working-beam, connecting-rod, crank and fly-wheel, converted into a rotative motion; and this motion can again, by the machinery of wheel-work, be adapted, either in velocity or power, to work grinding-stones, circular saws, threshing-mills, and other similar machines which require great velocity; or flatting mills, boring machines, rasping machines for logwood, lead-pipe drawing machines, &c. which require great power to give them motion, and are, therefore, performed with a less velocity. Machinery is, therefore, the organs by which motion is altered in its velocity, its period, and direction, and thus adapted to any purpose. All machinery will be found, upon minute investigation, to be only modifications of the six mechanical powers: the greatest number will be found to

consist chiefly of parts which have a motion of rotation round fixed axes, and derive all their energy from levers virtually contained in them: thus the pulleys, wheel and axle, are only modifications of the lever, and the screw is compounded of the lever with a variety of the inclined plane or wedge, so that the number of mechanical powers may be reduced to two, which assume an infinite variety of forms and motions. The theory and manner of calculating their effects will be found under *MECHANICS*.

In contriving any machinery, the engineer should always remember that nothing contributes more to the perfection of a machine, especially if it is massive and ponderous, than great uniformity of motion. Every irregularity of motion wastes some of the impelling power; and it is only the greatest of the varying velocity which is equal to that which the machine would acquire if moving uniformly throughout; for while the motion accelerates, the impelling force is greater than what balances the resistance then actually opposed to it, and the velocity is less than what the machine would acquire if moving uniformly; and when the machine attains its greatest velocity, it attains it because the power is then not acting against the whole resistance. In both of these situations, therefore, the performance of the machine is less than if the power and resistance constantly bore the same relation to each other, in which case it would move uniformly.

Every attention should, therefore, be given to this, and we should endeavour to remove all cause of irregularity through the whole machine. There are continual returns of strains and jolts from the inertia of the different parts acting in opposite direction. Although the whole momenta may always balance each other, yet the general motion is hobbling, and the points of support are strained. A great engine, so constructed, commonly causes the building to tremble; but when uniform motion pervades the whole machine, the inertia of each part tends to preserve this uniformity, and all goes smoothly. It is also deserving of remark, that when the communications are so contrived, that the uniform motion of one part produces uniform motion to the next, the pressures at the communicating points remain constant or invariable. Now the accomplishing of this is generally within the reach of mechanics, and the engineer should adapt his machinery to the particular case before him.

In the machinery for modifying and adapting a rotatory motion, the first which presents itself is the communication by means of toothed wheels acting on each other. This is the most general method in machinery, because it transmits the motion with certainty and accuracy, and if the teeth are properly formed, wheels, perhaps, consume less force in friction than any other method; but this is a subject understood by few mechanics. In the treatises on the construction of mills, and other works of this kind, are many instructions for the formation of the teeth of wheels, and almost every noted millwright has his own nostrums; but they are most of them defective in principle, or at least they are only correct in certain cases, which have by experiment or theory been determined, and are extremely fallacious when applied indifferently for all cases, as is the millwright's custom. An investigation of this subject, as applied to delicate mechanism, where accuracy rather than strength is the object, will be found in our article *Clock Work*, and we propose to give some further applications of those principles to wheels of large dimensions under *MILL Work*.

In the formation of the teeth of wheels, a small deviation from the perfect form is not, perhaps, of very great importance, except in cases where a very large wheel

drives a very small one, a case the judicious engineer should always avoid : the grand point to be attended to, is to adopt such a construction as will insure all the teeth of a wheel being precisely equal, and to make as great a number of them as the strength will admit. This will cause several teeth to be in action at once, and make the communication of the motion extremely smooth and uniform. To obtain strength in the cogs when they are made fine, the width or thickness of the wheel must be increased ; and this is one of the greatest practical improvements which has been made in machinery for these last twenty years. Formerly the best engineers, such as Smeaton, directed the teeth of large cog-wheels to be four and five inches distant from each other, or *pitch*, as the millwrights term it. Such wheels always act unequally upon each other in consequence of the point of contact of the large cogs constantly altering its position, becoming alternately nearer or farther from the centre of one or other of the wheels ; and this, tending to increase the acting radius of one, whilst it diminishes the other, causes their velocity and powers to vary at every cog that passes by, and the machine works by starts and jerks. The wheel-work of modern machinery is constructed with fine cogs, seldom more than one and a half or two inches pitch, and as much length of cog, or breadth of the wheel, as will make them sufficiently strong. We have seen some wheels in a large cotton mill which bore a strain equal to thirty horses' power, in which they were nine and twelve inches broad upon the face. Cog-wheels are found to work most smoothly when the teeth of the large wheel are made of hard wood, and the teeth of the small one made of cast iron, the acting surfaces being dressed or filed smooth and to the true figure. A mechanic, in contriving any machinery, should always bear in mind, that where he introduces cog-wheels, they should be as large in their diameters as is consistent with other circumstances, because this allows the teeth to be made finer in proportion to the power they are to bear, than if they were of smaller radii ; and the teeth, therefore, nearer the centre : it also occasions less pressure or drift upon the centre, and the wear of the whole will be equable. Another circumstance is worth notice, and should always be attended to, where it will not interfere with more important considerations ; this is, the direction in which any force is given to, and taken from, any piece of wheel-work : suppose, for instance, a water-wheel turning its axis, upon which is fixed a cog-wheel to give motion to a second wheel, for the purpose of driving any machinery ; now if this second cog-wheel is applied on that side of the first cog-wheel which is ascending, it will be opposite to that side of the wheel which is loaded with water, and is consequently descending. In this state the gudgeons of the water-wheel will have to bear (in some cases) double the strain of the power of the machine ; because the power, which is the weight of the water, is applied on one side the centre of the wheel, and is taken off by turning the second cog-wheel on the other side : the centre, or fulcrum, therefore, bears the whole power, and also the re-action to that power, in addition to the weight of its own parts ; in the same manner as the fulcrum of a steelyard or balance beam bears the whole of the weight suspended from either end, and its own weight also. On the other hand, suppose the second wheel applied on the descending side of the water wheel, this being on the same side of the centre, the pressure thereon will be far less than the power of the machine. In some cases (but not in a water-wheel), by the proper arrangement of the wheel work, the power may be made to operate to lift the centres, and thus in part relieve them from the weight of the wheel, so as actually to diminish the pressure of

friction of the pivots, when, by a contrary application, it would have increased it in the same degree. Similar advantages will attend the precaution of adapting the positions of different wheels upon their shafts to the different weights or strains they have to bear, so that the gudgeons at the two ends of any shaft may have an equal drift or pressure upon them. This will cause them to wear equally, and to have less friction, because they may be made smaller than where no such care is taken, still having sufficient strength. It is accomplished by considering the drift or pressure upon the centre of every wheel upon any axis, and placing the two gudgeons or pivots of the axis at a distance from each of the wheels, proportionate to the drift upon its centre. Thus, suppose a shaft has a cog-wheel fixed upon it, and a small wheel or pinion also fixed upon it at some distance from the wheel, the power is given to the axis by wheel-work operating upon the teeth of the pinion, and the re-action to this power is given by some machinery which the teeth of the large wheel actuates. In this case the drift on the centre of the pinion will be very considerable, because the power is applied near the centre of the axis ; but the wheel transmitting the power at a greater radius, will, perhaps, have much less drift on its centre (the proportion depending in some degree upon the direction in which the power and re-action are applied, as stated in our last observation) : if this is the case, the gudgeon at that end of the shaft, where the pinion is placed, should be lengthened out, so as to give the bearing point at a greater distance from it than the wheel, which should have its gudgeon placed much nearer to it, because less strain is to be borne. By this means the drift upon the two ends of the shaft will be equally divided between them : and though this proportion of the centre cannot be always accomplished without inconvenience, the engineer should always have it in view ; and then, where it is not practicable, he should attain the same end, by apportioning the strength or diameter of the gudgeons to the relative strains they have to bear.

An endless belt or strap is a very general method of transmitting rotatory motion : it is usually employed in cases where a very quick motion is to be created, and the re-action to be overcome is nearly equable. In such cases it has the advantage of wheel-work from its simplicity and the ease of its motion. Some curious properties belong to the endless strap, *viz* that the pulley or rigger it works upon must be largest in the middle, that is, the diameter must be greater in the middle of the pulley than at the edges, because the strap always rides on to the largest diameter of the pulley, and if this is not in the centre it will slip off at one side. It is not easy to give any satisfactory explanation of this fact, nor of another, that if, by accident, one of the pulleys is stopped while the strap is urged round by the motion of the other, it instantly flies off its pulley, unless the edge of the pulley should be much wider than the strap. This property is a great recommendation of it for some purposes, such as threshing mills, flour-dressing machines, lathes, cotton machines, &c. where any thing accidentally stopping the machines would destroy them if driven by wheel-work, but the strap slips round, and very soon comes off, so as to avoid all further danger. Belts of *girt-web*, such as are used for saddle girts, are sometimes used instead of leather straps, though these are undoubtedly preferable. The strap should be dressed to an equal thickness and breadth throughout, and the ends very neatly joined ; that is, of the same thickness there as at every other part. It is sometimes done by sewing, but the best method is by gluing them together, with a glue compounded of Irish glue, isinglass, ale grounds, and boiled linseed oil. The two ends being tapered away and

overlapped are united with this cement, and will be as flexible as any other part, but so strong that it will tear to pieces in any part rather than at the joint. A tool for equalizing the thickness and breadth of the straps for belts is described in the *Transactions of the Society of Arts*, vol. xxviii. p. 192, invented by Mr. Aubrey. They will by this means be rendered very correct, for nothing can be more unpleasant in machinery than the joint and thick places in the endless straps jerking over the riggers, and causing a violent drift upon the centres every time by the increased tension of the strap.

A mechanic, in calculating any extensive piece of machinery which is to depend upon straps for the communication of its motions, particularly if they are of great length to convey their motion to a considerable distance, and have much strain upon them, should always consider that such machinery will lose some of its velocity; that the wheels, which are turned by straps, will never make quite so many revolutions as they ought to do from a calculation of their diameters. This is generally supposed to arise from the strap slipping, in some degree, upon the surface of the wheels it passes over, but we are inclined to suspect that it arises from another cause which has not been investigated, *viz.* the elasticity of the strap: for instance, suppose that the distance between two wheels connected by a strap is ten feet, and that the strain upon the strap is such as to stretch or extend it two inches in that length on the side which bears the strain (called by mechanics the leading side), on the other, or returning side, there will be no strain, and therefore the strap will return to its original length. In such a case the wheel which is driven will lose in its motion two inches in every ten feet, because the strap gives out that quantity in leading to the wheel, but takes it up again in returning, as soon as the strain is removed from it.

Small machines are sometimes turned by a catgut band, the ends of which are united by a small steel hook and eye, the hook being fattened at one end and the eyes at the other. They are made with tubes, for the reception of the ends of the band, which are tapped with a screw within, and the band being tapered and screwed into the tube holds very fast. But to prevent it drawing out, a small quantity of rosin should be applied to the end of the band which projects through the tube, and a hot wire being touched to it fuses and hardens the end, that it will never draw out of the tube. This method is constantly used in small lathes, and works very neatly. The pulleys for a catgut-band should always be cut with a sharp angular groove, for the reception of the band, and it should not touch the bottom of it, or it will be liable to slip. For the same reason, the pulleys are best made of wood, because metals soon acquire a polish, which prevents the band holding firmly upon it. The wood should be cut with its grain across the direction of the band, that every part of the circumference may be of a similar texture.

Endless chains are sometimes used to communicate motion of wheels, and frequently cogs are formed on the wheels to be received into the links of the chains. This method is very practicable on particular occasions, and though it has not advantages to put it in competition with cog-wheels acting upon each other when they can be applied, it is in many instances a valuable resource to the engineer to convey motion to some distance when it requires to be accurate, and where it would injure the operation of the machine if any motion was lost by the slipping of bands. In making such chains the greatest care is necessary to have all the links precisely of one length, and the cogs very accurately fitted to them, or a great friction will be caused by the cogs

forcing themselves into spaces not exactly situated to receive them. The best way is to make the links in the manner of watch or clock chains, with iron plates, and holes drilled through them at equal distances, to receive cross pins upon which the cogs are to act. By this means the lengths may be made far more accurately than by bending the iron in the manner of common chain links.

Mr. Nicholson has described a spinning-wheel for children, at a charity-school, in which a large horizontal wheel, with a slip of buff leather glued on its upper surface near the outer edge, drove twelve spindles, at which the same number of children sat.

The spindles had each a small roller, likewise faced with leather, and were capable, by an easy and instantaneous motion, of being thrown in contact with the large wheel at pleasure; each child, therefore, could throw her own part of the apparatus into work, or cause it to stop as often or as long as she pleased.

The winding bobbins for yarn at the cotton mills operate on the same simple and elegant principles, which possesses the advantages of drawing the thread with an equal velocity, whatever may be the quantity of the bobbins, and cannot break it. The same mode of communication has been adopted in large work by Mr. Taylor, of Southampton, in his saw mills. In this the wheels acted upon each other by the contact of the end grain of wood instead of cogs. The whole made very little noise and wore very well: it was in use nearly twenty years. There is of consequence a contrivance to make the wheels bear firm against each other, either by wedges at the socket or by levers. This principle and method of transmitting mechanic power certainly deserve attention; particularly as the customary mode by means of teeth requires much skill and care in the execution; and after all wants frequent repair. We have seen it applied to a threshing machine, a small wheel on the threshing drum being applied in contact with the large wheel which gave motion to it, and a pressure sufficient to make it turn the machine was given by loading the socket for the spindle of the drum with a considerable weight. The same principle is capable of communicating motion with great accuracy when no force is required, as will be seen on a perusal of Mr. Troughton's ingenious method of dividing astronomical instruments. See GRADUATION.

The construction of bearings, pivots, gudgeons, or centres, of spindles, as they are indifferently termed, is a most important point; these parts being the principal seats of that friction which is the destruction of all machinery. Pivots are always made of iron or steel, both because these substances are better adapted for rubbing surfaces, and that their strength admits the pivot being as small as possible; the bearing, or bed to receive the gudgeons or pivots, should be of a softer metal, as brass, tin, or zinc, and kept well supplied with oil when at work. Hardened steel is a most admirable substance for pivots, which have a great strain to bear, and a rapid motion. The bearing or bed may also be made of the same material, and is the only instance where two bodies, having friction against each other, can with propriety be made of the same substance: for it is found, that where iron or soft steel surfaces are worked with a friction against parts of the same substance, the friction and abrasion are far greater than when a softer material, as brass, tin, hard wood, ivory, horn, &c. is used. The great difficulty of making hard steel pivots to spindles is the only reason they are not generally used; but there are some cases, in which nothing else can be employed: where steadiness and accuracy of motion are required, and great velocity at the same time. To obtain this accuracy, it is necessary that the

pivot should be fitted, and kept in accurate contact with the interior surface of its socket or pivot-hole, and this will present a sufficient access of oil, to prevent any other spindle, than one of hardened steel, from burning or heating by the friction, when in rapid motion; and the expansion occasioned by this heat increases the pressure and the friction, till the pivot becomes fixed in its socket, and will rather twist off than turn round in it. The spindle for a turning lathe must always be of hard steel; and even then, a failure of the supply of oil for a moment, will cause it to burn into the collar. Circular saw-spindles are frequently burnt in the same manner; their motion being very quick.

The best form of a gudgeon or pivot for a spindle, is that of a cylinder, with a flat shoulder, to prevent it from shifting its position endways. This form will bear most fairly and steadily; but it is necessary that the socket, or brass which contains the pivot, should be made in two halves, and put together with screws, that the halves may be screwed closer as the socket enlarges by wearing: but as this is only an imperfect method, because the pivot can never fit accurately after having been worn, a conical form is used for the pivots of axes requiring great accuracy, as these may be always made to fill their sockets, by pressing the cone farther into its socket. The cone is used in many turning lathes, whilst others are made very nearly cylindrical, with a shoulder; and as the collar is of hard steel, they do not wear in any sensible degree. Their advantage over the cone is, that they have no drift endways upon the opposite centre, as the cone has; though this is so slight in an acute cone, as to be of no importance in small machinery. In heavy works, such as the gudgeons of water-wheels, a conical figure would be highly improper, and has no advantage to recommend it; as such gudgeons seldom have any brass screwed down over them, their own weight being sufficient to keep them down, and they always fit true as they wear away. The most accurate and simple of all pivots is that which is similar to a piece of work, while turning in a lathe; the axis having a small hole made in each end of it, and the supports formed by sharp conical points, received into the holes; and one of them must be adjustable by a screw, to make it always fit the length of the spindle. It is usual to make the conical points on the ends of two screws, either of which may then be adjusted. The same thing may be accomplished by making conical points at the ends of the spindle, and forming the holes for its reception in ends of the two fixed screws, which can at all times be screwed up as the parts wear. It is the most perfect of all methods, but is not adapted to bear any great strain, because the screws will get loose, and all the objections to the conical spindle apply to it.

The pivot at the lower end of a vertical shaft, which has a great weight to sustain, as in a heavy horse-wheel, is very properly made of a hemispherical figure, and received into a proper cavity. A cylindrical pivot, having a flat end, is frequently used for large and heavy upright axes; but it is difficult to keep oil supplied to them, as the great weight presses it out from between the acting surfaces, and the gudgeon burns. To avoid this, some mechanics make a cleft across the lower face of the gudgeon, exactly in the manner of a screw-head. This getting full of oil, is constantly supplied to the acting surfaces.

We have seen an horizontal windmill, having a vertical axis 100 feet high, with sails and wheels of immense weight, all bearing upon one pivot. This was with the greatest difficulty kept in order; and it was necessary to keep a small stream of cold water always running into a pan, which surrounded the gudgeon, to keep it cold. This method of

watering, instead of oiling, a gudgeon is also used in paper-mills; but it cannot be recommended as a good method.

Friction-rollers are frequently used for supporting gudgeons, and, if made with great care, have the least friction which can be conceived; but they are liable to get out of order, if not made with extreme accuracy. See *MILL-Work*.

A great number of machines depend upon reciprocating motions, such as pump-mills, saw-mills, &c. Where the first mover has a circular motion, as a water-wheel, the reciprocating movement will be most conveniently produced by means of a crank; because it commences the change of motion by degrees, and does not suddenly urge the parts into motion in a contrary direction; nor suddenly check the movement again, but effects both changes without violence. It is proper, in such cases, to regulate the motion of the first mover by a fly-wheel, otherwise the resistance of the work, at the instant of the change of motion, is so small, that the machine would accelerate in that period, and then be checked again. The same may be accomplished by having several of the reciprocating movements and these act alternately, that when one requires the most power, the others take the least, so as to equalize the resistance to the first mover, and make the motion uniform. All reciprocating-machines labour under great disadvantages, from the circumstance that a great mass of matter must be put in motion, and this motion destroyed again. Thus, in a single pump forcing water through a great height of pipes, the column of water is, at every stroke the pump makes, put in rapid motion, which is wholly lost during the return of the pump-bucket for another stroke, when fresh impetus must be given to the water: now by applying a double acting pump, or two or three pumps acting at intervals, and the water regulated by an air-vessel, the motion will be very easy, because the column of water will be in constant motion through the pipes, and the momentum once given to it will continue as long as the machine is at work, instead of requiring a repetition of it at every stroke.

In every machine, the action of the moving power is transferred to the working point, through the parts of the machinery, which are material, inert, and heavy; or, to describe it more accurately, before the necessary force can be excited at the working point of the machine, the various connecting forces must be exerted in the different parts of the machine: and in order that the working point may follow out the impression already made, all the connecting parts or limbs of the machine must be moved in different directions, and with different velocities. Force is necessary for thus changing the state of all this matter, and frequently a very considerable force. Time must also elapse before all this can be accomplished. This often consumes, and really wastes, a great part of the impelling power. Thus, in a crane worked by men walking in a wheel, it acquires motion by slow degrees; because, in order to give sufficient room for the action of the number of men or cattle that are necessary, a very capacious wheel must be employed, containing a great quantity of inert matter. All of this must be put in motion by a very moderate preponderance of the men: it accelerates slowly, and the load is raised. When it has attained the required height, all this matter, now in considerable motion, must be stopped. This cannot be done in an instant, with a jolt, which would be very inconvenient, and even hurtful: it is therefore brought to rest gradually. This also consumes time. Nay, the wheel must get a motion in the contrary direction, that the load may be lowered into the cart or lighter; and this can only be accomplished by degrees. Then the tackle must be lowered down again

for another load, which also must be done gradually. All this wastes a great deal both of time and force, and renders a walking-wheel a very improper form for the first mover of a crane, or any machine whose use requires such frequent changes of motion. The same thing obtains, although in a lower degree, in the steam-engine, where the great beam and pump-rods, sometimes weighing many tons, must be made to acquire a very brisk motion in opposite directions, twice in every working stroke. It operates in a greater or a less degree, in all engines which have a reciprocating motion in any of their parts. Pump-mills are of necessity subjected to this inconvenience. In the famous engine at Marly, about $\frac{1}{4}$ ths of the whole moving power of some of the water-wheels is employed in giving a reciprocating motion to a set of rods and chains, which extend from the wheels to a cistern about three-fourths of a mile distant, where they work a set of pumps: thus the engine is, by such injudicious construction, a monument of magnificence, and the struggle of ignorance with the unchangeable laws of nature. In machines, all the parts of which continue the direction of their motion unchanged, the inertia of a great mass of matter does no harm; but, on the contrary, contributes to preserve the steadiness of the motion, in spite of small inequalities of power or resistance, or unavoidable irregularities of force in the interior part. But in all reciprocations, it is highly prejudicial to the performance; and, therefore, constructions which admit such reciprocation without necessity, are avoided by all the intelligent engineers.

In many machines, but generally in small works, what are called hearts, camms, snails, excentric wheels, &c. are a very excellent method of producing slight reciprocating movements to levers. From the rotatory motion of an axis, they have the great advantage of admitting any modification of the motion, to act suddenly or gradually, in either direction, at the pleasure of the maker. This is done, by wheels of a particular form, fastened upon an axis, and levers applied in contact with their circumferences, which receive a motion in proportion as the different radii of the wheels alter their lengths; and if, at any point of the motion, the lever is to be in a state of rest, the periphery of the wheel is, during that period, made a circular arc, and concentric with the axis. From the facility of producing any motion whatever by camms, it is an universal method, and applicable to all subjects; but still has objections, which will induce the engineer to neglect it in those instances, where any other movement will answer the same purpose. These objections are the great friction, and wear of the camms, which soon unfits them for accurate motion: this may in some measure be obviated by applying rollers in the ends of the levers, to receive the contact of the camm. Another objection is, that the camm is unfit for producing a double motion, because a spring or weight must be introduced to return the lever, and always keep it in contact with the camm. Now if this spring is only used to return the lever, it will operate very well; but if it is made so strong as to effect any operation of the machine, the friction will be great, and be a serious objection to the use of camms.

The principles of these movements, and practical directions for constructing camms for any kind of movement, is fully explained in our article *DIAGONAL Motion*, which renders it unnecessary to enlarge upon the subject in this place. Camms are used on a large scale in rolling-mills, for working the shears with which large iron bars are clipped into lengths. They are also employed in the machine for punching holes through the iron plates for boilers, weaving machines, &c.; and are in common use in the blowing ma-

chine used in iron forges; but it is a very injudicious application, and a common crank would be much better.

We once with great pleasure contemplated a very complicated machine, in which were many reciprocating parts necessarily operating only whilst moving in one direction; in the other, they had merely to return to repeat their operations. To produce this reciprocation, the inventor applied a crank, which was caused to revolve by the action of a pair of elliptical cog-wheels, each balanced on an axis passing through one of its foci. In this construction, the motion of the driven wheel and the crank it carried, was exceedingly variable, but by equal increments of alternate acceleration and retardation. Thus when the long radius of the first wheel was operating, it met the shortest radius of the other, therefore giving it and also the crank a rapid motion: in this state, the crank was returning to repeat its stroke, and with a quick stroke; but by the time it had completed half a revolution, the action was reversed, the short radius of the first wheel acting upon the long radius of the second, which was therefore with its crank at the slowest point of its movement: but the decrease of the motion, from the quickest to the slowest point of its revolution, being effected by equal increments, gave no shock to the machinery. The crank was of course, during the slow half of its movement, performing its work; and in the quick period, returning to fetch its stroke. By this judicious arrangement, the resistance to the first movement was very nearly equable: for when it had work to perform, the wheel-work gained a power upon the working point; but in returning, it caused it to urge the working point with such an increased velocity, as in some degree counterbalanced the diminished resistance: but in this, no loss was occasioned, because this increased velocity shortened the period of inaction hastening the return to a situation for repeating its operation.

These elliptical wheels are, in the hands of an able mechanic, a very useful contrivance, but they have not been much used in machinery, from the difficulties of forming their teeth with precision. In the *COMETARIUM*, (see that article,) they are introduced to represent the elliptic motions of comets, and we have seen two instances of their being used in large machines, where they operated with as much facility as circular wheels. It is to be observed, that a small excentricity of the ellipse, consequently a slight deviation from the circular figure, will produce a great inequality of their motion, because the increase of the acting radius of one wheel, is attended with a correspondent decrease of the other, so that to produce almost any differences of motion which can be required in practice, the excentricity of the wheels will be such as can easily be accomplished, and as will work with each other smoothly and accurately. When heavy stampers are to be raised in order to drop on the matter to be pounded, the wipers, by which they are lifted, should be made of such a form that the stamper may be raised by an uniform pressure, or with a motion almost imperceptible at first. If this is not attended to, and the wiper is only a pin sticking out from the axis, the stamper is forced into motion at once. This occasions a violent jolt to the machine, and great strains on its moving parts and their points of support: whereas, when they are gradually lifted at first, the inequality of desultory motion is never felt at the impelled point of the machine.

We have seen pistons of pumps moved by means of a double rack on the piston rod: a half wheel takes hold of one rack and raises it to the required height. The moment the half wheel has quitted that side of the rack, it lays hold of the other side and forces the piston down again. This has been proposed as a great improvement, by correcting

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the unequable motion of the piston, moved in the common way by a crank motion; but it occasions such abrupt changes of motion, that the machine is shaken by jolts. Indeed, if the movements were accurately executed, the machine would be soon shaken to pieces, if the parts did not give way by bending and yielding. Accordingly we have always observed that this motion soon failed, and was changed for one that was more smooth: a judicious engineer will avoid all such sudden changes of motion, especially in any ponderous part of a machine.

When several stampers, pistons, or other reciprocal movers are to be raised and depressed, common sense teaches us to distribute their times of action in a uniform manner, so that the machine may always be equally loaded with work. When this is done, and the observations in the preceding paragraph attended to, the machine may be made to move, almost as smoothly as if there were no reciprocations in it. Nothing shews the ingenuity of the engineer more, than the artful, yet simple and effectual contrivances, for obviating those difficulties that unavoidably arise from the very nature of the work to be performed by the machine, or in the power employed to actuate it.

In the contrivance of machinery, an engineer must not be tied down by too many inviolable maxims, because those contrivances which are the most improper in some situations will be the best of all in other cases. There is great room for ingenuity and good judgment in the management of the moving power, when it is such as cannot immediately produce the kind of motion required for effecting the purpose. We mentioned the conversion of the continued rotation of an axis into the reciprocating motion of a piston, and the improvement which was thought to have been made on the common and obvious contrivance of a crank, by substituting a double rack on the piston rod, and the inconvenience arising from the jolts occasioned by this change. We have been informed of a great forge, where the engineer, in order to avoid the same inconvenience arising from the abrupt motion given to the great sledge hammer of seven hundred weight, resisting with a five-fold momentum, formed the wipers for lifting it into spirals, which communicated motion to the hammer with scarcely any jolts whatever: but the result was, that the hammer rose no higher than it had been raised in contact with the wiper, and then fell on the iron bloom, with very little effect. The cause of its inefficiency was not guessed at; but it was removed, and wipers of the common form were put in place of the spirals.

In this operation the rapid motion of the hammer is absolutely necessary; it is not enough to lift it up, it must be raised up so as to fly higher than the wiper lifts it, and to strike with great force the strong oaken spring which is placed in its way. It compresses this spring, and is reflected by it with a considerable velocity, so as to hit the iron as if it had fallen from a great height: had it been allowed to fly to that height it would have fallen upon the iron with somewhat more force (because no oaken spring is perfectly elastic); but this would have required more than twice the time.

In employing a power which of necessity reciprocates, to drive machinery which requires a continuous motion (as in applying the steam engine to a cotton or corn grinding mill), there also occur great difficulties. The necessity of reciprocation in the first mover wastes much power, because the instrument which communicates such an enormous force must be extremely strong, and be well supported. The impelling power is wasted in imparting, and afterwards destroying a vast quantity of motion in the working beam. The skilful engineer will attend to this, and do his utmost

to procure the necessary strength of this lever, without making it a vast load of inert matter. He will also remark, that all the strains on it, and on its supports, are changing their directions in every stroke. This requires particular attention to the manner of supporting it: if we observe the old steam engines which have been long erected, we see that they have uniformly shaken the building to pieces. This has been owing to the ignorance or inattention of the engineer in this particular; they are much more judiciously erected now, experience having taught the most ignorant that no building can withstand their defultory and opposite jolts, and that the great movements must be supported by a frame work of wood or iron, independent of the building of masonry which contains it. The gudgeons of a water wheel should never rest on the wall of the building; it shakes it, and if set to work soon after the building has been erected, it prevents the mortar from taking firm bond, perhaps by shattering the calcareous crystals as they form.

When the engineer is obliged to rest the gudgeons in this way, they should be supported by a block of oak laid a little hollow: this softens all tremors, like the springs of a wheel carriage. This practice would be very serviceable in many other parts of the construction. It will frequently conduce to the good performance of an engine, to make the action of the resisting work, unequable, and accommodated to the inequalities of the impelling power. This will produce a more uniform motion in machines, in which the momentum of inertia is inconsiderable. There are some beautiful specimens of this kind of adjustment in the mechanism of animal bodies.

In many compound machines it is of consequence to be able to detach part of the movements while the others continue in motion. Thus in cotton-spinning machines, it is necessary to be able to cast off or stop any spindle at pleasure, without disturbing the rest; and in a large mill containing many machines, it is essential that any one may be released without interruption to the first mover. Such contrivances are called coupling or clutch-boxes: they are effected in various ways, some of which are detailed under COUPLING-BOX. But we wish here to describe a recent improvement, very generally adopted in cotton and woollen mills; the object of which is to avoid a jerk being given to any machine when it is put in action, from its being suddenly urged from a state of rest to a state of motion: for if the movement is to be rapid, nothing can be more destructive to the machine than the violence of the shock it receives from the common clutch-box. To avoid this, the arm which gives motion to the machine when the clutch of the running spindle is engaged with it, is not fixed fast upon the spindle, but is made in two halves screwed together upon a circular part of the spindle, and pinched upon it so fast by the screws, that it will have sufficient friction to turn the machine round in the ordinary course of its work, but slips round upon the spindle, if the resistance is greater than this friction, which thus becomes the measure of the power dealt out to the machine.

Suppose a machine of this kind at rest, the clutch is turned by the first mover with a considerable velocity, and is suddenly connected with the arm above described: now it requires some time (independent of any resistance or work of the machine) to put its parts in motion. In this time the arm slips round upon the spindle, but the friction acts constantly, and with an equable force upon the machine to turn it round. It commences its motion, which gradually accelerates, until it arrives at the same velocity as the driving spindle, and then the slipping of the box ceases, and the

machine proceeds in an uniform manner: still the box is a very useful provision in case of any accident happening to the machine to stop it, by any thing getting into its movements: the box then slips round without breaking the works. All machinery, which is exposed to the chance of great violence, should be provided with some equivalent contrivance, which permits the movement to slip when the machine is overloaded and would otherwise be broken. An instance of this will be seen in the *DREDGING Engine*; see that article. The same effect may be produced by conical wheels fitting into each other, in the manner of a valve and its seat. One of them being fixed to each spindle, will, when they are jammed into each other, communicate the motion, but permits it to slip if overloaded. A very ingenious application of this will be found, in the mortising machine of the block machines at Portsmouth (see *MACHINERY for manufacturing Ships' Blocks*), and another judicious application of it under *Log-wood Mill*.

Many other contrivances are in use for detaching or uniting motions at pleasure. In cog-wheels, the supports for the gudgeons are sometimes fitted up so as to be moveable, that the wheels can be separated to such a distance as to relieve each other's teeth. At other times one of the wheels is fitted on a round part of its axis, and united with it at pleasure by a clutch-box. Thus the wheels are always in motion, but one of them can be detached at pleasure from its axis, on which it slips freely. Bevelled cog-wheels are easily disengaged, by suffering the axis of one to move a little endways, and then their teeth are separated.

Wheels turned by straps are readily connected, or cast off, by removing the strap, but this is not easily done while the wheels are in motion; though some dextrous workmen are able to put on the straps when the wheels are going; but it is attended with much difficulty, and great danger, if the motion is quick, of catching the fingers in the strap. We have known an instance of a man's arm being torn away at the shoulder, by carelessness in performing this operation.

For disengaging the motion of a strap, the contrivance called the live and dead pulley is very ingenious: it consists of two pulleys placed close together upon any axis which is to receive a circular motion. The endless strap or band, by encompassing one of these pulleys, gives it a constant rotatory motion. Now one of them being fixed fast upon the spindle, and the other slipping freely round upon it, gives the means of turning or discontinuing the motion of the spindle at pleasure, by shifting the strap either upon the live or dead pulley, which, as they are exactly of the same size, and close to each other upon the spindle, is easily done. The live pulley is that which is fixed to its axis, so called from its causing life or motion to the spindle, and the machinery appended to it. The dead or idle pulley is that which slips upon its spindle; therefore, when the strap is caused to run upon it, it turns round without giving any motion to the spindle. This contrivance is extremely well adapted to give motion to small machinery, from the simplicity of its construction, and the facility with which it is put in motion or at rest. It possesses also another great advantage, *viz.* it occasions no sudden shock to the machinery at first starting, as it does not instantly communicate to it the full velocity. To illustrate this, suppose the strap running upon the dead pulley, and the machine therefore at rest, the leading side of the strap is in general conducted through a notch in a piece of board which is fitted in a groove, so as to have liberty of sliding in such a manner that it may conduct the strap to work upon either of the pulleys; but this is not necessary nor always attended to, for the person who attends the machine may, by the slightest pressure on the leading side strap

by his hand, cause it to shift upon the other pulley; but as this is not done instantly, it communicates the motion to the live pulley by degrees; for at first shifting, it begins upon a very narrow surface of the pulley, which is, therefore, urged into motion, but without violence to the machine, as the strap at first slips partially upon the surface of the live pulley, and this, as we have before stated, causes the strap to endeavour to escape from the pulley; but the attendant continues to press the strap on the leading side, and force it to act upon the live pulley, which having attained its full velocity, and the strap no longer slipping upon it, has no tendency to get off, unless the machine is overloaded, and then it will get off to the dead pulley. The live and dead pulley is very extensively used in cotton machinery, and is a very excellent contrivance; the only objection to it being that the bush in the centre of the idle pulley is liable to wear very loose in a short time. It is scarcely necessary to add, that the driving wheel for the strap of the live and dead pulley must be as broad on its edge as both the live and dead pulley together; indeed, it is generally a long cylindrical drum, which receives many straps for turning different machines.

A motion is frequently required in machinery, by which a wheel or axis is made to revolve in one direction for any required time, and then at pleasure changed, so as to revolve in the other direction. Various means may be used for effecting this purpose. The most common is by means of two equal and similar bevelled or contrate wheels, situated on the same axis, and their teeth towards each other. A third bevelled wheel is applied with its axis perpendicular to the former, and its teeth engaging at pleasure with either of the two wheels, which, as they turn the same way round, and can be made to act at one or other of the sides of the third wheel, so as to turn it in either direction, as it is engaged with either of the two wheels. This movement was applied by Mr. Smeaton to a machine he invented for drawing coals from coal-pits. In this the third wheel was a trundle, and could be, by a lever, made to work in the teeth of either of the cog-wheels which were mounted upon the axis of a water-wheel, and thus turned the trundle either way at pleasure, to draw up or let down the baskets or corves, which were suspended from a drum upon the axis of the trundle. Some mechanics have constructed the contrivance in a different manner, by fitting the two wheels upon a circular part of their spindle, and suffering them to turn round freely upon it. Their teeth are always engaged with the teeth of the third wheel, and, therefore, they are always revolving in opposite directions, and either can at pleasure be connected with the axis by a sliding clutch-box, but which is not long enough to engage both at once. The axis can, by this means, be made to revolve in the direction of either wheel at pleasure, by sliding the clutch-box towards that wheel.

We have seen a very ingenious application of the live and dead pulley to this purpose, for a crane in a cotton mill, to take up and down the goods, work-people, &c. It was invented by Mr. Henry Strutt, and has been applied in his cotton mills at Belper, Derbyshire. In this machine it was necessary to have a motion which could be turned either way at pleasure, to draw up or let down the basket; but the double wheel-work above described was evidently improper, from the sudden jerk it would have given at the instant of changing the motion. It was effected in this manner: an axis which gave motion to the crane barrel, has two pair of live and dead pulleys upon it, and also a brake wheel to stop the motion, which is situated between the two pair: an endless strap is conducted to each pair, being turned by a long drum placed parallel to the axis of the pulleys, and kept in constant motion by the mill. One of these endless straps is crossed

between the drum and its pullies, but the other is not, therefore one pair of the live or dead pullies are always revolving in one direction, and the others are turning in an opposite way. Both straps are conducted through guides fixed to a sliding rail, by which the straps can be shifted both at once, sideways. When this rail is in a position that the straps are both upon their dead pullies, the axis and brake wheel are at rest, and in this position the rail has a tendency to remain, unless forced by hand. On moving the rail one way from the quiescent point, one of the straps is thrown on its live pulley, and the spindle turns with it, winding up the basket. By moving the rail in the other direction beyond its quiescent point, this strap is shifted on to its dead pulley, and becomes inactive; but the other strap operates on its live pulley, to turn the spindle in the opposite direction, and lets down the basket. We shall describe this very useful and curious machine in its place among the cotton machinery. See MANUFACTURE of Cotton.

Logwood rasping engines, screw presses, and some other machines, require a motion to work them forwards to a certain extent, and then the direction is to be reversed to draw them back, which requires but very little power to effect it. In this case the motion may be effected by a pair of cog-wheels turning each other, and thus communicating the motion for one direction in which it is to perform the work. A couple of pullies are fixed on the respective axes near the cog-wheels, and an endless strap connects them, but the strap is so long, that when the cog-wheels are in gear, the strap hangs slack, and does not operate: but to reverse the movement, the sockets for one of the gudgeons of the driving spindle or axis is made to shift, that the distance between the centre of the two wheels may be increased, so as to disengage the teeth of the wheels, and the strap becomes tight, and turns the wheels back; but on bringing the wheels together again, the strap becomes slack, and the wheels resume their original course.

Screws are, of all the mechanical powers, the most frequently used in machines, though not always as moving parts, being chiefly introduced for uniting and retaining the parts. They are not so constantly employed as acting movements, on account of their friction, and the trouble of making them; they are, nevertheless, a very useful agent on many occasions, and possess the advantage of accurately retaining any movement they make, and producing an extremely slow motion with ease, and, when it is required, with the most perfect accuracy. No engineer will employ screws for a rapid motion, as their friction and great wear renders them unfit for such situations. To the endless screw acting on the teeth of cog-wheels, this objection does not apply so forcibly, because the great number of teeth on which the screw operates successively, do not wear so fast as the nut of a female screw would under the same circumstances, and the friction is far less, because the screw is not enclosed all round its thread. The endless screw or worm is useful on many occasions to obtain a slow motion, which it does in a very simple manner; but, for the purpose of obtaining a quick motion, it should never be used, on account of the friction and consequent wear. This is seen in the common roasting jack.

In many situations in which moving screws are used, the same effects may be produced in the most simple and convenient manner by Mr. Bramah's method of producing and applying a more considerable degree of power to all kinds of machinery requiring motion and force, than by any means at present practised for the purpose. This method, for which, on the 31st of March 1796, he obtained a patent, consists in the application of water, or other dense fluids, to various engines, so as, in some instances, to cause them to act with immense

force; in others, to communicate the motion and powers of one part of a machine to some other part of the same machine; and lastly, to communicate the motion and force of one machine to another, though removed to a great distance from each other, and where their local situations preclude the application of all other methods of connection. The principle of this invention is the same with the hydrostatic paradox, but its various applications to useful purposes is due to Mr. Bramah. The simplest form is for a press, or machine, to raise an enormous weight to a small height: a metallic cylinder sufficiently strong, and bored perfectly smooth and cylindrical, has a solid piston fitted into it, which is made perfectly water tight, by leather packing round its edge, or other means used in hydraulic engines. The bottom of the cylinder must be made sufficiently strong, with the other parts of the surface, to resist the greatest strain which can ever be applied to it. In the bottom of the cylinder is inserted the end of a small tube, the aperture of which communicates with the inside of the cylinder, and introduces water or other fluids into it: the other end of the pipe communicates with a small forcing pump, by which the water can be injected into the cylinder under its piston: the pump has of course valves to prevent the return of the water. Now suppose the diameter of the cylinder to be twelve inches, and the diameter of the piston of the small pump or injector only one quarter of an inch, the proportion between the two surfaces or ends of the said pistons will be as 1 to 2304; and supposing the intermediate space between them to be filled with water, or other dense and incompressible fluids, any force applied to the small piston will operate upon the other in the above proportion, viz. as 1 to 2304. Suppose the small piston or injector to be forced down when in the act of forcing or injecting with a weight of 20 cwt. which can easily be done by means of a long lever, the piston of the great cylinder would then be moved up, with a force equal to 20 cwt. multiplied by 2304. Thus is constructed a hydro-mechanical engine, whereby a weight amounting to 2304 tons can be raised by a simple lever, in much less time through equal space, than could be done by any apparatus constructed on the known principles of mechanics, and it may be proper to observe, that the effect of all other mechanical combinations is counteracted by an accumulated complication of parts, which renders them incapable of being usefully extended beyond a certain degree, but in machines acted upon, or constructed on this principle, every difficulty of this kind is obviated, and their power subject to no finite restraint. To prove this, it will be only necessary to remark, that the force of any machine acting upon this principle can be increased, *ad infinitum*, either by extending the proportion between the diameter of the injector and the great cylinder, or by applying greater power to the lever actuating the small pump. On this principle very wonderful effects may be produced instantaneously, by means of compressed air. Suppose a large cylinder, furnished with a piston in the same manner as before described, a globular vessel is used, made of copper, iron, or other strong material, capable of resisting immense force, similar to those used for air guns: it has a strong tube of small bore, in which is a stop-cock: one of the ends of this tube communicates with the great cylinder beneath its piston, and the other end with the globe. Now suppose the great cylinder to be of the same diameter as that before described, and the small tube equal to one quarter of an inch diameter, which is the same as the injecting pump before-mentioned for the press: then suppose that air is injected into the globe (by the common method) till it presses against the cock with a force equal to 20 cwt, which can be done; the consequence will be, that when the cock is opened, the piston will be instantly

moved in the great cylinder, with a power or force equal to 2304 tons, and it is obvious, as in the case before-mentioned, that any other unlimited degree of force may be acquired by machines or engines thus constructed. By the hydrostatic principle, the power and motion of any machine may be transferred or communicated to another, let their distance and local situation be what they may. Suppose two small tubes or cylinders, in the inside of each of which is a piston made water and air-tight, a tube may be conveyed under ground or otherwise, from the bottom of one cylinder to the other, to form a communication between them, notwithstanding their distance be ever so great. Let this tube be filled with water, or other fluid, until it touches the bottom of the two pistons; then, by depressing the piston of one cylinder, the piston of the other will be raised. The same effect will be produced, *vice versa*; thus bells may be rung, wheels turned, or other machinery put invisibly in motion by a power being applied to either cylinder.

By these means, it is obvious, that most commodious machines of prodigious power, and susceptible of the greatest strength, may readily be formed. If the same multiplication of power be attempted by toothed-wheel pinions and racks, it is scarcely possible to give strength enough to the teeth of the racks, and the machines become very cumbersome, and of great expence. But Mr. Bramah's machine may be made abundantly strong in very small compass. It only requires very accurate execution. The hydrostatic principle on which it depends has been well known for nearly two centuries, and it is a matter of surprise that it has never before been applied to any useful practical purpose.

The application which Mr. Bramah has made of this truly valuable principle is very general: it was first applied for presses instead of large screws, for which purpose it is greatly superior in every respect. Presses being generally moved by the strength of men alone, the saving of power becomes a great object; and this it accomplishes, having no proportion of the friction of the screw, and immensely greater power. In a screw-press, it requires nearly as much labour to unscrew as to screw it up, an evidence of the enormous friction of a screw, when acting against a great pressure: but the hydrostatic-press only requires a cock to be opened to let out the water from beneath the piston, which then descends quickly, by its own gravity, or the elasticity of the substances under the pressure. But the greatest convenience of the hydrostatic principle is, that its power can so easily be transmitted to any distance, and in any direction, by means of pipes conducted along in situations where all other means of conveying the motion would be complicated, and expensive in the extreme. Thus, in a large paper-mill, an injecting-pump may be kept in constant action by the water-mill, or steam-engine, and inject water into an air-vessel, from which pipes are conducted to presses in all parts of the mill, and by simply opening a cock at any press, any required pressure will be instantly given by the elasticity of the confined air operating on the enlarged surface of the piston of any press. The air-vessel has, of course, a safety-valve, to allow the escape of the water when the pressure becomes so great as to endanger the rupture of any of the vessels; for it is to be observed, that the power of this principle is irresistible, when the pump is worked by a mill, and will burst any vessels, without the least appearance of strain on the moving parts of the pump.

In Mr. Bramah's extensive work-shops at Pimlico, and another at Mill-Bank, London, the steam-engines which turn the lathes, boring-machines, planing-machines, &c. work a small injecting-pump, as above-mentioned, and small copper pipes are laid to every part of the works, and

by cocks admitting it into various cylinders, many powerful operations are performed: it works an immense press for bending strong iron bars, or breaking cast-iron for the foundery. It moves the carriage of the planing-engine; and he has brought the methods of packing the cylinders to such perfection, that they are employed to make the most delicate adjustments in the parts of the machine. (See a full description of this in *PLANING Engine*, and also *PRESS, Hydrostatic*.) In another part of the factory, it works a crane for lifting the heaviest goods, by merely opening a cock, and lowers them down, by opening another, with the utmost safety. A very large *Flood-gate* is also raised up by two cylinders. (See that article.) It may be used for turning the bridges of canals. (See *CANAL*.) On the whole, we cannot conclude this article, without recommending the hydrostatic principle very strongly to engineers, as a method the most perfect of all others of communicating motion, which is to act only for short extents, or with great power, as it can so easily be conducted through any circuitous rout, and loses so little power by friction. The ease with which it is relieved from the action, or caused to operate in a contrary direction, is not its smallest advantage; and by means of the air-vessel the power may be accumulated while the machine is preparing for action, and then an immense power suddenly given. We have little doubt the hydrostatic-press would answer the best of any method for expressing oil. The present oil-press is described under *OIL-Mill*, and operates by a wedge, driven by repeated blows of a heavy stamper. The method is ingenious; but great part of the power is expended in friction, as is evident from the wedge requiring nothing to retain it, as it is driven, the friction over-balancing all the re-action of the substances pressed.

A motion is very frequently required in machinery for giving to any piece of wheel-work an increased or diminished velocity at pleasure. The most complete of these are the *EXPANDING Riggers* (see that article); but many other means may be employed. Thus, on two parallel spindles, which are to turn each other, place a number of wheels, increasing in size by regular steps, the smallest wheel of one spindle being opposite to the largest of the other. The same endless strap will fit any pair of them, and give a great variety of powers and velocities: the same may be effected by having a number of cog-wheels; and, instead of a strap, using an intermediate cog-wheel, which can be applied to connect any pair of the wheels at pleasure. A very ingenious application of double cones is used in a cotton-machine, called the double-speeder. See *MANUFACTURE of Cotton*, also Mr. Braithwaite's *CRANE*.

It is very customary to add what is called a fly to machines. This is a heavy disk or hoop, or other mass of matter, balanced on its axis, and so connected with the machinery, as to turn briskly round with it. This may be done with the view of rendering the motion of the whole more regular, notwithstanding unavoidable inequalities of the accelerating forces, or of the resistances occasioned by the work: it then becomes a regulator. Suppose the resistance to a machine extremely unequal, and the impelling power perfectly constant; as when a bucket-wheel is employed to work one pump; when the piston has ended its working-stroke, and while it is going down the barrel, the power of the wheel being scarcely opposed, it accelerates the whole machine, and the piston arrives at the bottom of the barrel with considerable velocity; but in the rising again, the wheel is opposed by the column of water now pressing on the piston: this immediately retards the wheel; and when the piston has reached the top of the barrel, all the acceleration is undone, and is to begin again. The motion of

such a machine is very hobbling; but the surplus of accelerating force, at the beginning of a returning stroke, will not make such a change in the motion of the machine, if we connect the fly with it; for the accelerating momentum is a determinate quantity: therefore, if the radius of the fly be great, this momentum will be attained by communicating a small angular motion to the machine. The momentum of the fly is as the square of its radius, therefore it resists acceleration in this proportion; and although the overplus of power generates the same momentum of rotation in the whole machine as before, it makes but a small and imperceptible addition to its velocity. If the diameter of the fly be doubled, the augmentation of rotation will be reduced to one-fourth. Thus, by giving a rapid motion to a small quantity of matter, the great acceleration during the returning stroke of the piston is prevented. This acceleration continues, however, during the whole of the returning stroke, and at the end of it the machine has acquired its greatest velocity. Now, the working stroke begins, and the overplus of power is at an end. The machine accelerates no more; but if the power is just in equilibrium with the resistance, it keeps the velocity which it has acquired, and is still more accelerated during the next returning stroke. But now, at the beginning of the subsequent working-stroke, there is an overplus of resistance, and a retardation begins and continues during the whole rise of the piston; but it is inconsiderable in comparison of what it would have been without the fly: for the fly, retaining its acquired momentum, drags forwards the rest of the machine, aiding the impelling power of the water-wheel. It does this by all the communications taking into each other in the opposite direction; the teeth of the intervening wheels are heard to drop from their former contact on one side, to a contact on the other. By considering this process with attention, we easily perceive that in a few strokes the overplus of power, during the returning stroke, comes to be so adjusted to the efficiency, during the working stroke, that the accelerations and retardations exactly destroy each other, and every succeeding stroke is made with the same velocity, and an equal number of strokes is made in every succeeding minute. Thus the machine acquires a general uniformity with trifling periodical inequalities. It is plain, that by sufficiently enlarging either the diameter, or the weight of the fly, the irregularity of the motion may be rendered as small as we please. It is much better to enlarge the diameter: this preserves the friction more moderate, and the pivots wear less. For these reasons, a fly is, in general, a considerable improvement in machinery, by equalling many exertions that are naturally very irregular. Thus a man, working at a common windlass, exerts a very irregular pressure on the winch. In two of his positions in each turn, he can exert a force of near seventy pounds without fatigue, but in others he cannot exert above twenty-five; nor must he be loaded with much above this in general. But if a large fly be connected properly with the windlass, he will act with equal ease and speed against thirty or even forty pounds.

If any permanent change should happen in the impelling power, or in the resistance, the fly makes no obstacle to its production in its full effect on the machine, and it will be observed to accelerate or retard uniformly, till a new general speed is acquired, exactly corresponding with this new power and resistance. Many machines include in their construction movements which are equivalent with this intentional regulation, a flour-mill for example. There is another kind of regulating fly, consisting of wings whirled briskly round till the resistance of the air prevents any great acceleration. This is a very bad one for a working machine,

for it produces its effect by really wasting a part of the moving power. Frequently it employs a very great and unknown part of it, and robs the proprietor of much work. It should never be introduced into any machine employed in manufactures, except in the instance of letting down heavy weights, where a waste or re-action to power is the object.

Some rare cases occur where a very different regulator is required, when a certain determined velocity is found necessary: in this case, the machine is furnished at its extreme mover with a conical pendulum, consisting of two heavy balls hanging by rods, which move in very nice and steady joint at the top of a vertical axis. It is well known, that when this axis turns round, with an angular velocity suited to the length of those pendulums, the time of a revolution is determined.

Thus, if the length of each pendulum be $39\frac{1}{2}$ inches, the axis will make a revolution in two seconds very nearly. If we attempt to force it more swiftly round, the balls will recede a little from the axis, but it employs as long time for a revolution as before; and we cannot make it turn swifter, unless the impelling power be increased beyond all probability: in which case, the pendulum will fly out from the centre till the rods are horizontal, after which every increase of power will accelerate the machine very sensibly, as it then becomes a simple fly. Watt and Boulton have applied this contrivance with great ingenuity to their steam engines when they are employed for driving machinery for manufactures which have a very changeable resistance, and where a certain speed cannot be much departed from without great inconvenience. They have connected this recess of the balls from the axis (which gives immediate indication of an increase of power, or a diminution, or resistance,) with a cock, which admits the steam to the working cylinder. The balls flying out cause the cock to close a little, and diminish the supply of steam, if the impelling power diminishes the next moment, and the balls again approach the axis, and the rotation goes on as before, although there may have occurred a very great excess or deficiency of power. The same contrivance may be employed to raise or lower the feeding sluice of a water-mill employed to drive machinery. (See MILL.) Suppose all resistance removed from the working point of a machine furnished with a very large or heavy fly, immediately connected with the working point; when a small force is applied to the impelled point of this machine, motion will begin in the machine, and the fly begin to turn, continue to press uniformly, and the machine will accelerate. This may be continued till the fly has required a very rapid motion. If, at this moment, a resisting body be applied to the working point, it will be acted on with very great force; for the fly has now accumulated, in its circumference, a very great momentum.

If a body were exposed immediately to the action of this circumference it would be violently struck, much more will it be so, if the body be exposed to the action of the working point, which perhaps makes one turn while the fly makes a hundred. It will exert a hundred times more force (very nearly) than at its own circumference. All the motion which has been accumulated in the fly, during the whole progress of its acceleration, is exerted in an instant at the working point, multiplied by the momentum, which depends on the proportion of the parts of the machine. It is thus that the coining press performs its office; nay, it is thus that the blacksmith forges a bar of iron. Swinging the great sledge hammer round his head, and urging it with force the whole way, this accumulated motion is at once extinguished by impact on the iron. It is thus we drive a nail; and it is

thus, that by accumulating a very moderate force exerted during four or five turns of a fly, the whole of it is exerted on a punch, set on a thick plate of iron, such as is employed for the boilers of steam engines, and the plate is pierced as if it were a piece of cheese. This accumulating power of a fly has occasioned many, who think themselves engineers, to imagine, that a fly really adds power or mechanical force to an engine; and, not understanding on what its efficacy depends, they often place the fly in a situation where it only added a useless burden to the machine. If intended for a mere regulator, it should be near the first mover: if it is intended to accumulate force in the working point, it should not be far separated from it. In a certain sense, a fly may be said to add power to a machine, because by accumulating into the exertion of one moment the exertions of many, we can sometimes overcome an obstacle that we never could have balanced by the same machine unaided by the fly. See FLY-WHEEL.

It is this accumulation of force which gives such an appearance of power to some of our first movers. When a man is unfortunately caught by the teeth of a paltry country mill, he is crushed almost to mummy. The power of the stream is conceived to be prodigious, and yet we are

certain, upon examination, that it amounts to the pressure of no more than fifty or sixty pounds; but this force has been acting for some time, and there is a millstone of a ton weight whirling twice round in a second. This is the force that crushed the unfortunate man; and it required it all to do it, for the mill stopped. We have been informed of a mill in the neighbourhood of Elbingroda, in Hanover, where there was a contrivance which disengaged the millstone when any thing got entangled in the teeth of the wheels. On being tried with a head of cabbage, it crushed it, but not violently, and would, by no means, have broken a man's arm.

It is hardly necessary to recommend simplicity in the construction of machines. This seems now sufficiently understood. Multiplicity of motions and communications increase friction; augment the unavoidable losses by bending and yielding in every part; expose all the imperfections of workmanship; and have a great chance of being indistinctly conceived; and are therefore constructions without science. We shall consider this object as applied to large machinery under *MILL Work*.

MACHINERY for manufacturing Cotton. See MANUFACTURE of Cotton.

Malt Liquors

MALT Liquors have different names as well as different virtues, properties, and uses, both from the different manners of preparing the malt, whence they are distinguished into *pale* and *brown*; and from the different manners of preparing or brewing the liquors themselves, whence they are divided into *beer* and *ale*, *strong* and *small*, *new* and *old*.

Malt drinks are either pale or brown, as the malt is more or less dried on the kiln; that which is the slenderest dried, tinging the liquor least in brewing, and therefore being called *pale*: whereas that higher dried, and as it were roasted, makes it of a higher colour. A mixture of both these makes an amber colour; whence several of these liquors take their name.

Now, it is certain, the pale malt has most of the natural grain in it, and is therefore the most nourishing; but for the same reason, it requires a stronger constitution to digest it. Those who drink much of it, are usually fat and sleek in their bloom, but are often cut off by sudden fevers; or, if they avoid this, they fall early into a distempered old age.

The brown malt makes a drink much less viscid, and fitter to pass the several strainers of the body; but, if very strong, it may lead on to the same inconveniences with the pale; though a single debauch wears off much more easily in the brown.

Dr. Quincy observes, that the best pale malt liquors are those brewed with hard waters, as those of springs and wells, because the mineral particles, with which these waters are impregnated, help to prevent the cohesions of those drawn from the grain, and enable them to pass the proper secretions the better; as the viscid particles of the grain do likewise defend these from doing the mischief they might otherwise occasion. But softer waters seem best suited to draw out the substances of high-dried malts, which retain many fiery particles in their texture, and are therefore best lost in a smooth vehicle.

For the differences in the preparation of malt liquors, they chiefly consist in the use of hops, as in beer; or in the more sparing use of them, as in ale.

The difference made by hops is best discovered from the nature and quality of the hops themselves: these are known to be a subtle grateful bitter: in their composition, therefore, with this liquor, they add somewhat of an alkaline nature, *i. e.* particles that are sublime, active, and rigid. By which means, the rosy viscid parts of the malt are more divided and subtilized; and are, therefore, not only rendered more easy of digestion and secretion in the body, but also, while in the liquor, they prevent it from running into such cohesions as would make it rosy, vapid, and sour.

For want of this, in unhopped drinks, that clammy sweetness, which they retain after working, soon turns

them acid, and unfit for use; which happens sooner or later, in proportion to the strength they receive from the malt, and the comminution they have undergone from fermentation.

It is a common opinion, that ale is more diuretic than beer, that is, liquor less hopped more than that with a greater quantity of hops in it: which may hold in some constitutions, because ale being more smooth, softening, and relaxing, where urine is to be promoted by enlarging the passage, as in thin, dry constitutions, this is the most likely to effect it. But where the promoting of urine is to be done by attenuating and breaking the juices, and rendering them more fluid, it is certainly best answered by those drinks which are well hopped.

As to the dispute, whether or no hops tend to breed the stone, it is too long to enter upon here. Quincy is of opinion, there is but little reason for the affirmative side of the question; and, in general, makes no scruple to say, that, for one constitution damaged by beer, there are numbers spoiled by ale. This last manifestly fouls the glands, stuffs the vessels with slime and viscosity, makes the body unwieldy and corpulent, and paves the way for cachexies, jaundice, asthma, and at last incurable dropsies. The urinary passages, also, which it is supposed to clear, will, in time, be filled by it with slough, and matter of as ill consequence as gravel.

The different strengths of malt liquors also make their effects different. The stronger they are, the more viscid parts they carry into the blood; and though the spirituous parts make these imperceptible at first; yet when those are evaporated, which will be in a few hours, the other will be sensibly felt by pains in the head, nausea, sickness at the stomach, and lassitude or listlessness to motion. This, those are the most sensible of, who have experienced the extremes of drinking these liquors and wines; for a debauch of wine they find much sooner worn off, and they are much more lively and brisk afterwards, than after intemperately using malt liquors, whose viscid remains will be long before they be shaken off.

Malt liquors, therefore, are, in general, the more wholesome for being small, *i. e.* of such a strength as is liable to carry a small degree of warmth into the stomach, but not so great as to prevent their being proper diluters of the necessary food. Indeed, in robust people, or those who labour hard, the viscidities of the drink may be broken into a convenient nourishment; but in persons of another habit and way of living, they serve rather to promote obstructions and ill humours.

The age of malt liquors is the last thing by which they are rendered more or less wholesome. Age seems to do nearly the same thing as hops; for those liquors which are longest kept are certainly less viscid; age breaking the vis-

acid parts, and, by degrees, rendering them smaller, and fitter for secretion.

But this is always determined according to their strength; in proportion to which, they will sooner or later come to their full perfection, as well as decay; for, when ale or beer is kept till its particles are broken and comminuted as far as they are capable, then it is that they are best; and, beyond this, they will be continually on the decay, till the finer spirits are entirely escaped, and the remainder becomes vapid and sour.

MALT Distillery. This is an extensive article of trade, and by which very large fortunes are made. The art is to convert fermented malt liquors into a clear inflammable spirit, which may be either sold for use in the common state of a proof strength, that is, the same strength with French brandy; or is rectified into that purer spirit usually sold under the name of spirit of wine; or made into compound cordial waters, by being distilled again from herbs and other ingredients. See **BREWING, SPIRITS, and WASH.**

To brew with malt in the most advantageous manner, it is necessary, 1. That the subject be well prepared; 2. That the water be suitable and duly applied; and, 3. That some certain additions be used, or alterations made, according to the season of the year, and the intention of the operator; and by a proper regulation in these respects, all the fermentable parts of the subject will thus be brought into the tincture, and become fit for fermentation.

The due preparation of the subject consists in its being justly malted and well ground. When the grain is not sufficiently malted it is apt to prove hard, so that the water can have but very little power to dissolve its substance; and if it be much malted, a part of the fermentable matter is lost in that operation. The harder and more stinty the malt is, the finer it ought to be ground; and in all cases, when intended for distillation, it is advisable to reduce it to a kind of finer or coarser meal. When the malt is thus ground, it is found, by experience, that great part of the time, trouble, and expence of the brewing is saved by it, and yet as large a quantity of spirits will be produced; for thus the whole substance of the malt may remain mixed among the tincture and be fermented and distilled among it. This is a particular that very well deserves the attention of the malt distiller, as the trade is at present carried on; for the dispatch of the business, and the quantity of spirit procured, are more attended to than the purity or perfection of it.

The secret of this matter depends upon the thoroughly mixing, or briskly agitating and throwing the meal about, first in cold, and then in hot water; and repeating this agitation after the fermentation is over, when the thick turbid wash being immediately committed to the still, already hot and dewy with working, there is no danger of burning, unless by accident, even without the farther trouble of stirring, which in this case is found needless, though the quantity be ever so large, provided that requisite care and cleanliness be used; and thus the business of brewing and fermenting may very commodiously be performed together, and reduced to one single operation. Whatever water is made choice of, it must stand in a hot state upon the prepared malt, especially if a clear tincture be desired, but a known and very considerable inconvenience attends its being applied too hot, or too near to a state of boiling, or even scalding with regard to the hand. To save time in this case, and to prevent the malt running into lumps and clods, the best way is to put a certain measured quantity of cold water to the malt first; the malt is then to be stirred very well with this, so as to form a sort of thin uniform paste or

pudding; after which the remaining quantity of water required may be added in a state of boiling, without the least danger of making what, in the distillers language, is called a pudding.

In this manner the due and necessary degree of heat in the water, for the extracting all the virtues of the malt, may be hit upon very expeditiously, and with a great deal of exactness, as the heat of boiling water is a fixed standard which may be let down to any degree by a proportionate mixture of cold water, due allowances being made for the season of the year, and for the temperature of the air.

This little obvious improvement, added to the method just above hinted for the reducing brewing and fermentation to one operation, will render it practicable to very considerable advantage, and the spirit improved in quality as well as quantity.

A much more profitable method than that usually practised for the fermenting malt for distillation, in order to get its spirit, is the following: Take ten pounds of malt reduced to a fine meal, and three pounds of common wheat-meal: add to these two gallons of cold water, and stir them well together, then add five gallons of water boiling hot, and stir all together again. Let the whole stand two hours, and then stir it again, and when grown cold, add to it two ounces of solid yeast, and set it by loosely covered in a warmish place, to ferment.

This is the Dutch method of preparing what they call the wash for malt spirit, whereby they save much trouble, and procure a large quantity of spirit: thus commodiously reducing the two businesses of brewing and fermenting to one single operation. In England the method is to draw and mash for spirit as they ordinarily do for beer, only instead of boiling the wort, they pump it into large cookers, and afterwards run it into their fermenting backs, to be there fermented with yeast. Thus they bestow twice as much labour as necessary, and lose a large quantity of their spirit by leaving the gross bottoms out of the still for fear of burning.

All simple spirits may be considered in their different states of low wines, proof spirit, and alcohol, the intermediate degrees of strength being of less general use; and they are to be judged of only according as they approach to, or recede from, these. Low wines, at a medium, contain a sixth part of pure inflammable spirit, five times as much water as spirit necessarily arising in the operation with a boiling heat. Proof goods contain about one-half of the same totally inflammable spirit; and alcohol entirely consists of it. See **SPIRITS.**

Malt low wines, prepared in the common way, are exceedingly nauseous; they have, however, a natural vinosity, or pungent agreeable acidity, which would render the spirit agreeable to the palate, were it not for the large quantity of the gross oil of the malt that abounds in it. When this oil is detained in some measure from mixing itself among the low wines, by the stretching a coarse flannel over the neck of the still, or at the orifice of the worm, the spirit becomes much purer in all respects; it is less fulsome to the taste, less offensive to the smell, and less milky to the eye. (Shaw's Essay on Distillery.) When these low wines, in the rectification into proof spirits, are distilled gently, they leave a considerable quantity of this gross fetid oil behind them in the still along with the phlegm; but if the fire be made fierce, this oil is again raised and brought over with the spirit; and being now broken somewhat more fine, it impregnates it in a more nauseous manner than at first. This is the common fault both of the malt distiller and

of the rectifier; the latter, instead of separating the spirit from this nasty oil, which is the principal intent of his process, attends only to the leaving the phlegm in such quantity behind, that the spirit may be of the due strength as proof or marketable goods, and brings over the oil in a worse state than before. To this inattention to the proper business of the process, it is owing that the spirit, after its several rectifications, as they are miscalled, is often found more stinking than when delivered out of the hands of the malt distiller. All this may be prevented by the taking more time in the subsequent distillations, and keeping the fire low and regular, the sudden stirring of the fire, and the hasty way of throwing on the fresh fuel, being the general occasions of throwing up the oil by spurts, where the fire in general, during the process, has not been so large as to do that mischief.

The use of a *balneum Mariæ*, instead of the common still, would effectually prevent all this mischief, and give a purer spirit in one rectification, than can otherwise be procured in ten, or indeed according to the common methods at all.

Malt low wine, when brought to the standard, or proof spirit, loses its milky colour, and is perfectly clear and bright, no more oil being contained in it than is perfectly dissolved by the alcohol, and rendered miscible with that proportion of phlegm, which is about one-half the liquor; its taste also is cleaner though not more pleasant; there being less of the thick oil to hang on the tongue in its own form, which is not the case in the low wines, where the oil, being undissolved, adheres to the mouth in its own form, and does not pass lightly over it.

When proof spirit of malt is distilled over again, in order to be rectified into alcohol, or, as we usually call it, spirits of wine, if the fire be raised at the time when the faints begin to come off, a very considerable quantity of oil will be raised by it, and will run in the visible form of oil from the nose of the worm. This is not peculiar to malt spirit, but the French brandy shews the same phenomenon, and that in so great a degree, that half an ounce of this oil may be obtained from a single piece of brandy.

Malt spirit, more than any other kind, requires to be brought into the form of alcohol, before it can be used internally, especially as it is now commonly made up in the proof state, with as much of this nauseous and viscous oil as will give it a good crown of bubbles. For this reason it ought to be reduced to an alcohol, or totally inflammable spirit, before it is admitted into any of the medicinal compositions. If it be used without this previous caution, the odious taste of the malt oil will be distinguished among all the other flavours of the ingredients.

Malt spirit, when it has once been reduced to the true form of an alcohol, is afterwards more fit for all the curious internal uses than even French brandy, it being after this purification a more uniform, hungry, tasteless and impregnable spirit, than any other spirits which we esteem so much finer.

A pure spirit being thus procured, should be kept carefully in vessels of glass or stone, well stopped to prevent the evaporation of any of its volatile part. If preserved in casks, it is apt to impregnate itself very strongly with the wood. The quantity of pure alcohol obtainable from a certain quantity of malt, differs according to the goodness of the subject, the manner of the operation, the season of

the year, and the skilfulness of the workman; according to which variations, a quarter of malt will afford from eight or nine, to thirteen or fourteen gallons of alcohol. This should encourage the malt distiller to be careful and diligent in his business, as so very large a part of his profit depends wholly on the well conducting his processes.

After every operation in this business, there remains a quantity of faints, which in their own coarse state ought never to be admitted into the true spirit; these are to be saved together, and large quantities of them at once wrought into alcohol. It is easy to reduce these to such a state, that they will serve for lamp spirits. Their disagreeable flavour being corrected by the adding of aromatics during the distillations, the reducing them to a perfect and pure alcohol is practicable, but not without such difficulties, as render it scarcely worth the trader's while. One way of doing it is by distilling them from water into water, and that with a very slow fire. By this means a pure alcohol may be made out of the foulest faints.

The malt distiller always gives his spirit a single rectification *per se*, in order to purify it a little, and make it up proof, but in this state it is not reckoned fit for internal uses, but serves to be distilled into geneva and other ordinary compound strong waters for the vulgar.

The Dutch, who carry on a great trade with malt spirit, never give it any farther rectification than this, and it is on this account that the malt spirit of England is in general so much more in esteem. The Dutch method is only to distil the wash into low wines, and then to full proof spirit; they then directly make it into geneva, or else send it as it is to Germany, Guinea, and the East Indies, for the Dutch have little notion of our rectification. Their spirit is by this means rendered very foul and coarse, and is rendered yet more nauseous by the immoderate use they make of rye meal. Malt spirit, in its unrectified state, is usually found to have the common bubble proof, as the malt distiller knows that it will not be marketable without it.

The whole matter requisite to this is, that it have a considerable portion of the gross oil of the malt well broke and mixed along with it; this gives the rectifier a great deal of trouble if he will have the spirit fine; but in the general run of the business, the rectifier does not take out this oil, but breaks it finer, and mixes it faster in by alkaline salts, and disguises its taste by the addition of certain flavouring ingredients. The spirit loses in these processes the vinosity it had when it came out of the hands of the malt distiller, and is, in all respects, worse, except in the disguise of a mixed flavour. Shaw's Essay on Distillery.

The alkaline salts used by the rectifier, destroying the natural vinosity of the spirit, it is necessary to add an extraneous acid in order to give it a new one. The acid they generally use is the *spiritus nitri dulcis*; and the common way of using it is the mixing it to the taste with the rectified spirit: this gives our malt spirit, when well rectified, a flavour somewhat like that of French brandy, but this soon flies off; and the better method is to add a proper quantity of Glauber's strong spirit of nitre to the spirit in the still. The liquor in this case comes over impregnated with it, and the acid being more intimately mixed, the flavour is retained. See *SPIRITUS nitri dulcis*.

Manchester

MANCHESTER, a market town in the hundred of Salford and county of Lancaster, England, is seated on the banks of the small rivers Irk, Medlock, and Irwell, at the distance of 185 miles from London and 32 from Liverpool. In point of commercial and political importance, though not a corporation, it is undoubtedly the second town in the kingdom. The whole population, according to the parliamentary census of 1800, amounted to 84,053 persons, of whom 44,500 were engaged in different branches of trade: 44,900 were females, and 39,110 were males. The amazing increase of population in this town is shewn by returns obtained in the years 1773 and 1811. In the former year there were 29,951 persons; and in the latter 98,573. The parish of Manchester comprehends several of the contiguous townships, the whole population of which is 136,370.

Manchester appears, from the testimony of Mr. Whitaker, to be a town of great antiquity. A station occupied by the ancient Britons is supposed to have been settled here 500 years before the Christian era. It did not, however, deserve the name of a town till after the invasion of this island by the Romans, when it became one of the fortified retreats of the brave but undisciplined natives. At this period it was called Mancenion, that is, the "place of tents;" but Agricola, who conquered it A.D. 79, changed its name to Mancunium. It was afterwards called Manduesfledum, and Mancaltræ, from which latter term its present appellation is evidently derived. The Romans, upon achieving the conquest of this station, built an extensive castle upon the spot now denominated Castle-field, situated near the conflux of the Medlock with the Irwell; but every vestige of this is removed to make room for modern buildings. After having retained it in continued possession for somewhat more than 400 years, the declining fortunes of Rome compelled the legionary soldiers to abandon it to the original possessors, who in their turn soon yielded it to their new conquerors and tyrants the Saxons. During the dynasties of that ferocious people, Manchester was several times a place of military conflict, being seated on the immediate confines of the Northumbrian kingdom. Edward the Elder, king of the Mercians, is said to have fortified and rebuilt a considerable part of it, which time and violence had united to destroy. At the period of the grand Domesday survey, two churches appear to have existed here, called St. Mary's and St. Michael's. Albert de Gresley obtained from the Conqueror the lordship

of the manor. In 1301 his grandson, Thomas, granted a charter to his burgesses of Manchester, constituting their town a free borough. Lord de la Warr, the last male heir of this family, laid the foundation of the collegiate church, which tended, in no small degree, to promote its increase and improvement. This town in early times was a place of sanctuary, and one of the eight places to which that privilege was confirmed by Henry VIII. in 1540. The year following, however, it was removed to Chelster, which the statute declares "had a strong gaol and a mayor, and had not the wealth, credit, great occupings and good order which Manchester had." In 1605, a pestilence raged here, and carried off upwards of 1000 persons. Upon the breaking out of the civil war between Charles I. and the parliament, Manchester decidedly espoused the republican cause, and successfully resisted several sieges by the royal army, under the earl of Derby. Notwithstanding these circumstances, however, the inhabitants seem to have honoured the restoration of Charles II. with particular marks of joy.

From this short sketch it will readily be perceived that, in an historical point of view, Manchester is only entitled to a very small share of general attention: though regarded as a manufacturing town, it is deservedly distinguished above every other in England. When it first began to be noted for its manufactures is uncertain; but in the time of Edward VI. Manchester cottons, Manchester rugs, and Manchester friezes are frequently mentioned in various acts of parliament. In 1650, its trade is described as "not inferior to that of many cities in the kingdom, chiefly consisting in woollen friezes, fustians, sack-cloths, mingled stuffs, caps, inkles, tapes, points, &c. whereby not only the better sort of men are employed, but also the very children by their own labour can maintain themselves. There are, besides, all kinds of foreign merchandize brought and returned by the merchants of the town, amounting to the sum of many thousand pounds." About this time great quantities of linen yarn seem to have been imported here from Ireland, which being wrought into cloth, was reshipped for the Irish market. It was not, however, till after the middle of the last century, that Manchester rose to a pre-eminent rank among our manufacturing towns; a rank for which it is chiefly indebted to the ingenuity and invention of Mr. Hargreave and Sir Richard Arkwright. Previous to the year 1760, all the cotton yarn manufactured in the country was spun by hand, upon that well known domestic instrument

called a one-thread wheel. Shortly after this period, Mr. Hargreave constructed a machine denominated a *jenny*, by which one person was enabled to spin from twenty to forty threads at a time. These machines soon came into general use, but were much limited in their employment till the year 1775, when sir Richard brought the improvements of his predecessor to much greater perfection. This gentleman having established his extensive manufactories here, made Manchester the principal seat of the spinning trade, the rapid increase of which produced a corresponding increase in the buildings and population of the town. See the preceding articles of ARKWRIGHT, vol. ii. and COTTON, vol. x. for further particulars. In Brayley's "Beauties of England," vol. iii., Derbyshire, is an interesting and ample memoir of sir Richard Arkwright, with accounts of the present state and processes of the cotton manufactures.

As Manchester, notwithstanding its extent and political importance, is not a corporate town, the government is vested in a headborough, called the boroughreeve, and two constables. These are chosen annually from the most respectable of the inhabitants by a jury impanelled by the steward of the manor, at the courts leet, which are held by the lord of the manor twice every year at Easter and Michaelmas. The boroughreeve is usually one of the gentlemen who has served as constable for the preceding year, and is treated perhaps with more respect (the paraphernalia of a mace-bearer excepted), than any mayor in the kingdom. The chief duty of this officer is to preside at public meetings, and to distribute certain charities, denominated "boroughreeve charities," all the judicial functions connected with the police being executed by the constables and their deputies. A court of requests is held every month for the recovery of small debts; and every Wednesday and Saturday several respectable magistrates sit in the court-room of the New-Bayley for the administration of justice in pleas of almost every description, whether civil or criminal. Quarter sessions also are held four times a-year; and, from press of business, the court is sometimes obliged to continue its sittings for nearly a fortnight.

This town is divided into two portions by the river Irwell, which receives the Irk at a short distance from the collegiate church. The situation of Salford is very similar to that of Southwark, the communication between the two towns being kept up, as in London, by three bridges thrown across the river at different places. The most ancient of these is called the "Hanging bridge," Old, or Salford bridge, and is supposed to have been originally founded in the time of the Romans. The present, built in the reign of Edward III., was formerly very dangerous for foot passengers, but in 1778 it underwent a thorough repair and extension. Blackfriar's bridge, erected about fifty years ago, is constructed entirely of wood, and flagged for foot passengers only. But the finest bridge over the Irwell is the New bridge, commonly called the New Bayley bridge, which was founded in 1785, and is constructed wholly of stone. It consists of three large arches, and a fourth of smaller dimensions, left open in support of the duke of Bridgewater's right to a towing path to his quay, in Salford, agreeably to the tenor of the act, enabling His Grace to form his extensive canals. Six bridges are here thrown across the Irk, the chief of which are Huntsbank bridge, situated near the college, and Scotland bridge: nine are thrown over the Medlock, which runs in a serpentine course through the southern suburbs of the town. Oxford-street bridge forms a part of a street of that name. A variety of other bridges lie across the numerous canals which intersect the suburbs at different places, and at Knotmill, in the vicinity of Castle-field, is a

very noble tunnel, through which the Rochdale canal passes, not far from its junction with that of the late duke of Bridgewater's.

With respect to the plan and buildings of this town, it may be remarked, that the portion of it called the Old Town consists of a very motley assemblage of old and new houses, closely huddled together, and exhibiting little elegance in their exterior appearance. Even the new streets, though much superior to the old, are usually narrow, except in a few instances where they have been improved by the acts of 1775 and 1791. In these latter, however, there are a number of very excellent modern buildings. Mosley-street and Portland place would do honour to the capital itself. Grosvenor-square, when finished, will probably rival the finest in the kingdom. The suburbs of Ardwick-green and Salford crescent are peculiarly pleasant, and contain some handsome houses, which are mostly occupied by the wealthy manufacturers.

The churches and other public edifices of this town are numerous, but few of them are distinguished for architectural beauty. The College, or parish church, founded, as already mentioned, by lord de la Warr, bishop of Durham and rector of Manchester, is a venerable building in the rich ornamented style of the 15th century. In the interior its appearance is confused and heterogeneous. The windows still retain many rich remains of the painted glass with which they were formerly ornamented. The roof is of elegant wood-work, interspersed with carved figures of angels playing upon different musical instruments. In front of the gallery, on each side of the clock, are suspended the colours of the 72d regiment, raised in this town by subscription during the American war, whose noble conduct at the siege of Gibraltar is still remembered with exultation by every lover of his country, and particularly by the inhabitants of Manchester. Adjoining to this church are a number of small chapels well worthy of the attention both of the architect and the antiquary. A view of this church, with a particular account of its history and architectural peculiarities, written by J. H. Markland, F. S. A. are given in the third volume of "The Architectural Antiquities of Great Britain."

St. Ann's church, situated at the end of the square to which it gives name, is distinguished for its handsome appearance. It was founded by lady Ann Bland in 1709, in compliment to whom it was dedicated to the saint whose name it bears. The church of St. Mary, situated between Dean-gate and the river Irwell, is admired for the beauty and fine proportions of its spire, which measures 186 feet in height. The lanthorn which supports it is peculiarly striking, being composed of eight noble Ionic pillars, surmounted by a large globe, upon which is placed a massy cross. St. John's church is built in the style which is called modern Gothic. In the vestry are several pictures, and a beautiful window of stained glass. Two of the windows in the body of the church are also decorated with fine painted glass. The other churches in this town are St. Paul's in Turner-street, St. James's in George-street, St. Michael's in Angel-street, St. Clement's in Lever-street, St. Stephen's near Bolton-street, St. George's in the neighbourhood of Newton-lane, and St. Peter's, which terminates the prospect down Dawson-street and Mosley-street. The latter was designed and executed by James Wyatt, esq. In Salford is Trinity chapel, a neat stone edifice of the Doric order.

Besides these churches there are three others also belonging to the establishment, situated in the adjoining townships of Ardwick, Chorlton, and Pendleton, which, from their vicinity to Manchester, may not improperly be considered as belonging to it. Numerous chapels and meeting-houses, appropriated for the public worship of dissenters of almost every

denomination, are likewise dispersed through various parts of the town. Catholics are numerous here, and the Methodists are found to comprise a very considerable proportion of the whole population.

The vast number of excellent charitable institutions with which Manchester abounds are highly creditable to the benevolence, liberality, and public spirit of its inhabitants. Indeed, in this respect, this town is not surpassed by any in the British empire, whether the suitableness of the buildings for their respective purposes, or the liberal contributions by which they are supported, are taken into view. Among these establishments, Chetham's-Hospital, commonly called the College, is first deserving of notice, by priority of foundation. It owes its existence and entire support to the munificent bequest of Humphrey Chetham, esq. of Clayton, whose will is dated the 16th of December 1651. At first, the number of boys clothed and educated here amounted only to forty; but from an increase in the value of the estates belonging to the foundation, the number was augmented more than thirty years ago to eighty. The building appropriated to this charity is situated on a lofty rock, near the confluence of the rivers Irk and Irwell, immediately adjoining to the collegiate church already mentioned, to which indeed it formerly belonged. Upon this spot Mr. Whitaker supposes the Romans had their prætorium, or summer camp; and certainly the situation was admirably adapted for that object. In a large gallery, in this edifice, is a public library, likewise founded by Mr. Chetham, which now contains upwards of 15,000 volumes in various languages, and in almost every branch of science or literature, besides some very valuable manuscripts. The Infirmary, Dispensary, Lunatic Hospital, and Asylum, are all included in one spacious building, situated in the front of Lever's Row, which is considered as the highest ground in the town. The foundation of the first edifice was laid in 1753, for the reception of forty patients; but the number was soon afterwards doubled, and now there are 160 beds appropriated for the use of the sick. The Lunatic Hospital was opened in 1766, and the Dispensary in 1792. The annual subscriptions for the support of these institutions, amount to several thousand pounds. Here are two poor-houses, one of which was erected in 1792, on the side of the Irk, nearly opposite the College; and the other built the year following, at the upper end of Greengate in Salford. Both of them are handsome buildings, and admirably fitted up for the purpose to which they are appropriated. The Lying-in-Hospital was instituted in 1790, and not only provides professional aid for in-door patients, but likewise for the assistance of such poor married women as find it inconvenient to leave their own houses. The House of Recovery is intended chiefly for the reception of patients afflicted with contagious fevers. The other principal charities are the strangers-friend-society, instituted in 1791, and the boroughreeve's charity: the former designed for the relief of strangers, and the latter for the aid of the poor inhabitants in general. The Free-school is an excellent foundation, which owes its origin to Hugh Oldham, bishop of Exeter. In this school the greater part of the clergy of the town and neighbourhood have been educated, as well as many noblemen. There are, besides, several inferior charity and Sunday schools in various parts of Manchester.

Though in every respect a manufacturing town, Manchester has not wholly neglected the promotion of literature and science. Societies, having this object in view, are numerous. The chief of them are the Literary and Philosophical, instituted by Dr. Thomas Percival in 1781; and the Philological Society, which commenced its meetings in 1803. Here are also two very extensive public

circulating libraries; the former founded in 1757, and the latter in 1792. The Manchester Agricultural Society was established in 1767, and has for its object the encouragement of the useful arts in general, by the distribution of premiums for scientific discoveries. A laudable practice is also adopted, of granting premiums to cottagers, who support their families without parochial aid; and in some instances likewise, honest and good servants are rewarded, by honorary presents. The repository, designed to encourage and reward industrious females, has proved highly serviceable to many individuals, and is therefore justly entitled to liberal and careful support.

Besides those already noticed, many other public buildings and institutions, intended either for useful purposes or for amusement, may properly claim attention in this place. The Theatre, a commodious and extensive building, was erected in 1807. It is open during seven months of the year, and can in general boast of a very respectable company of performers. The gentlemen's Concert-room is elegant and capacious, and will accommodate upwards of 1200 persons. This is supported by a voluntary subscription; and strangers are admitted with a subscriber's ticket. There are likewise very excellent new and commodious assembly-rooms for balls, card-assemblies, &c. The New-Bayley, or Penitentiary house, is well deserving attention, both on account of the extent of the edifice and arrangement of its parts, and also for the economy observed in the interior. Immediately above the entrance is a large room, where the sessions are held; and adjoining to it are several commodious rooms for the magistrates, jurors, &c. Beyond this, in the centre of a large area enclosed by lofty walls, stands the prison, an extensive building in the shape of a cross, three stories high. It is remarkable for the cleanness with which it is kept, as well as for its regulations. Prisoners, not confined for capital crimes, are allowed the free exercise of their respective trades. A workhouse, on a large scale, has also been lately built.

A new structure, called the Manchester Commercial Building, or Exchange, was commenced in the year 1806, from designs by Mr. Harrison, architect. It was completed in January 1809, and is appropriated to the use of the merchants and manufacturers of the town, who subscribed certain shares of 50*l.* each, to defray the expences of its erection. The building comprises an exchange-room, dining-room, drawing-room, ware-rooms, shops, and counting-houses, a suite of rooms for the post-office, with extensive cellars under the whole. It is built of stone, and presents a simple, but classical façade, with demi-columns of the Grecian Doric order. The exchange-room is very spacious, containing an area of 4000 superficial feet, in the centre of which is a glazed dome, 40 feet in height, supported by eight fluted columns of the Ionic order. Over a part of this room is a gallery, or semicircular suite of rooms, appropriated to an extensive library, belonging to Mr. Ford, a respectable bookseller of this town, whose large catalogue contains a valuable assortment of scarce, curious, and interesting works.

The Trade of Manchester consists chiefly, but not entirely, in the manufacture of cotton goods. Velvetts, checks, a variety of small articles, such as filleting, tapes, laces, gartering, &c. are likewise made in great quantities. The silk manufacture has advanced rapidly here within the last ten years; and a manufactory for making and finishing hats is now carried on to a great extent. The profusion of goods made here is conveyed, by means of the Irwell and the numerous canals which intersect the town, to different ports both on the eastern and western coast. Liverpool, however, is the principal mart for the exportation of the cottons; and be-

tween that town and Manchester there is a constant and rapid communication both by land and water-carriage.

Manchester has two markets, called the old and the new, both of which are held twice a week on Tuesdays and Saturdays: the latter is the principal one for provisions; the former being mostly frequented for transacting the manufacturing business of the town with the country traders. Most of the streets are paved and lighted, and are guarded at night by about 200 watchmen. For the regulation of parochial affairs, Manchester is divided into fourteen districts. It gives title of duke to the noble family of Montague, some of whom have been distinguished characters. In the paths of literary fame, however, it can claim little distinction; but Byrom and Falkner may be properly ranked with what Fuller calls "the worthies of the place."

The environs of this town abound with old mansions, respectable villas, and a number of modern seats. Ancoats-hall, the manorial mansion-house, is a venerable building, the parts of which are disposed in a most curious and gro-

tesque manner. Hulme-hall, or Holme, is an edifice of a similar kind, exhibiting a remarkable specimen of ancient domestic architecture. It stands on the edge of a shelving bank of the Irwell, and exteriorly offers to the view a most romantic and picturesque object. Heaton-house, the seat of the earl of Wilton, lies about four miles to the north-east of the town. The house, a handsome modern structure of stone, stands on a commanding situation, in the midst of a very noble park, finely decorated with venerable trees and numerous thriving plantations. The other principal seats are Trafford-house, Alkington, and Smedley-hall; near which last is Broughton-hall, formerly the property of the Stanleys, earls of Derby. Every part of the surrounding country displays the highest state of agricultural improvement, and in times of prosperity presents one vast scene of enterprize and industry. *Beauties of England and Wales*, vol. ix. Aikin's *History of Manchester, and its Environs*, 4to. by J. Aston. The *Manchester Guide*, 12mo. 1804. Whitaker's *History of Manchester*, 2 vols. 4to. 1771.

Manufacture

MANUFACTURE is popularly used to signify the work itself; and by extension, the like work carried on independently in different parts of the country.

In this sense we say, the *cotton* manufacture, *woollen* manufacture, *silk* manufacture, *velvet* manufacture, *tapestry* manufacture, *musslin* manufacture, &c. manufacture of hats, stockings, &c.

By 23 Geo. II. c. 13. if any person exports any tools or utensils used in the silk, linen, cotton, or woollen manufactures, he forfeits the same, and 200*l.*; and the captain of the ship, having knowledge thereof, 100*l.* And if any captain of a king's ship, or officer of the customs, knowingly suffers such exportation, he forfeits 100*l.* and his employment, and is for ever made incapable of bearing any public office. And every person collecting such tools for exportation, shall on conviction forfeit them, and 200*l.* (See also 14 Geo. III. c. 71.) By 21 Geo. III. c. 37. the above penalties on the captain of the ship and officer of the customs are augmented to 200*l.*; and a person having in his custody, or procuring to be made any such tool, shall forfeit the same, and 200*l.*, and be imprisoned for twelve months. Prosecution on this clause to be within twelve months after the offence committed. By 22 Geo. III. c. 60. any person exporting any such tools, shall forfeit the same, and 500*l.*; and any officer of a ship, conniving at it, shall forfeit 500*l.*, and if it be a king's ship, forfeit also his office, and be incapacitated.

Much was done under the auspices of the magnanimous prince Edward III., for establishing our domestic manufactures, by prohibiting the exportation of English wool, and the importation or wear of foreign cloths or furs, and

by encouraging cloth-workers from other countries to settle here.

MANUFACTURE, *Cotton*, one of the leading and most important branches of our national industry and commerce.

The history of its astonishing progress in the last century, the successive improvements in the machinery, which have been made by various inventors, and the extent of the trade, with other curious important facts, are detailed under the article COTTON: it is needless, therefore, to recapitulate these circumstances, and we shall proceed at once to describe this extensive manufacture, as conducted on the most improved system in some of our largest cotton-mills. Many of our readers may have viewed a cotton-mill with wonder, but not with intelligence, nor with leisure to trace the steps by which the wool from the bag ultimately assumes the form of a very fine thread. Bewildered by such a complication of machinery all in motion, very few, we imagine, are able to recollect, with distinctness and intelligence, the essential part of the processes by which the form of the cotton is so wonderfully changed. Such readers will not think a page or two misemployed, in giving a brief account of the different operations the cotton passes through, from the raw cotton or cotton wool, as imported, to the finished thread; and we shall afterwards enlarge upon each subject, and describe the machinery by which these operations are effected in the most expeditious and perfect manner. For the explanation of these, we have appropriated 13 of our plates, which are entitled *Cotton Manufacture*.

Cotton, it is well known, is the produce of a shrub in the warmer climates of the East and West Indies, and even in the more temperate countries which border on the Levant. It comes to us packed in bags, without any further

preparation than being pretty carefully picked out of the pod in which it grows; but still much dirt, husk, and other impurities remain in it. The cotton wool is imported either in bags or in bales: the bags weigh from $1\frac{1}{2}$ cwt. to 5 cwt., and the bales usually weigh $3\frac{1}{2}$ or $3\frac{3}{4}$ cwt. On arriving at the cotton-mill these are unpacked, and the contents examined at the same time it is turned over and beaten with a stick, and the gross impurities picked out with the fingers. This is called *sorting*, and the object of the beating is to soften and open the fibre of the cotton, so as to expose every part. The sorting is performed immediately when the bags of cotton are opened, but it has still to undergo a second examination, called *picking*; the principal object of the first examination, or sorting, being intended to ascertain the quality of the cotton, and to find what kind of goods it is best adapted for manufacturing, and in this examination the coarsest impurities and yellow damaged parts are picked out.

After sorting the cotton, it is carried to the *batting machine*, and the coarser sorts of cotton to the *opening machine*, which is known to the workmen by the name of *devil*. In the batting machine, the cotton is spread upon a platform of ropes strained very tight, and a number of rods strike very smartly upon it, by which they open the fibres and loosen the knots of cotton preparative to the succeeding operations: at the same time the violence of the batting loosens and shakes out all dirt, dust, and cotton seeds, of which the cotton in its raw state contains a great number, and which would be very prejudicial to the operations of the more delicate machines. The cotton, when first packed up in the bags, is compressed very closely, for the convenience of stowage, and this condenses it into a hard matted mass; but the batting machine, striking it violently with small sticks, causes the fibres, by their natural elasticity, and the motion occasioned among them, to gradually loosen and disengage themselves, and the cotton, by repeated strokes, recovers all its original volume.

The *opening machine* has the same objects, and produces the same effects, though in a very different manner, as it consists of a rapidly revolving cylinder, on which a great number of iron teeth, or spikes are fixed, which tear and open the cotton against other similar teeth, which are fixed in a stationary half cylinder or hood, enclosing the other. The batting machine is used for the finer kind of cotton; and the opening machine, which acts in a more rapid though less effective manner, is employed upon the coarser sorts. After batting or opening, the cotton is again picked, to remove those finer particles of dirt which were before enveloped in the cotton, but are exposed by the operation of the machine. It is performed by women, who remove all extraneous matter, and every particle of yellow or damaged cotton. The perfection of the article to be produced, depends in a great degree on the care with which the picking is performed, and this is almost the only process, in the cotton spinning, which cannot be performed by machinery, because it necessarily requires a discretionary power.

The cotton wool being picked clean, is next *mixed*, that is, the contents of different bags are mixed together with a view of obtaining a similarity in the quality of the cotton which is to be spun. In this operation the greatest art of cotton-spinning consists, and it is that department in which experience alone guides the manufacturer. By a judicious mixture of different sorts of cotton, some spinners will produce a very fine and capital yarn, from such cotton as would, if spun alone, or improperly mixed, only produce coarse and low priced goods. The mixture is effected by making a pile or heap, consisting of successive layers, of the different kinds

of cotton which are to be mixed; then by raking away a small quantity at a time from the edges of the heap, striking the rake from the top to the bottom, through all the different layers, the cotton will be very equally mixed. Sometimes the cotton wool is dyed, and different colours are mixed together. It is now spread out, very evenly and regularly, upon a long cloth, which is rolled up and carried to the

Carding machine.—This consists of a number of cylinders, covered with wire teeth or cards, and revolving with considerable velocity in opposite directions, nearly in contact with each other, and covered by a dome also lined with cards. The cotton, being introduced among these, is continually combed, or carded, by the teeth, until almost every individual fibre is separated and drawn straight, and every little knotty and entangled part disengaged. By passing gradually through the machine from one cylinder to another, the cotton is dispersed lightly and evenly among the teeth over the whole surface of the last, or finishing cylinder, from which it is detached by the mechanism in a continued fleece. This is drawn off, and lapped upon a cylinder turned slowly round by the machine, until the fleece has made a great number of turns upon the cylinder: it is then broken off, by dividing it at one part, so that it forms a fleece called a lap, which is the length of the circumference of the cylinder, and consisting of fifteen or twenty thicknesses, by which admirable contrivance very great regularity is obtained in the thickness of the lap, because if any one part of the fleece produced by the machine is thinner or thicker than it ought to be, in consequence of any irregularity in the spreading of the cotton-wool upon the cloth, previous to carding, such irregularity will have no sensible effect upon the ultimate thickness of the lap, because it is composed of thirty or forty strata, and there is no probability that the inequalities of these several strata will fall beneath each other, but every chance that they will be equally dispersed through the whole, and thus correct each other. The lap, when taken off, is laid flat on a cloth, which, with it, is rolled up and conveyed to a second carding-machine, called the *finishing card*, while the first is called the *breaker*. In this second card it undergoes a similar process to the first, but instead of the fleece being received on a cylinder, it is contracted by passing through a funnel, in which the fleece, being hemmed in on both sides, is gradually contracted to a thick roll, which may be continued to any length as long as the machine is supplied with cotton. This roll or band of cotton is drawn off between two rollers, which compress it into a pretty firm, flat ribband, about two inches broad. The rollers deliver it into a tin can, placed to receive it, and in this it is removed to the

Drawing Frame.—This machine consists of several pairs of rollers, between which the cotton is passed, and every successive pair it is drawn through moves, by means of the wheel-work, with a greater velocity than those preceding it, so as to stretch out the band or sliver of cotton, in the same manner as it would be drawn out, if one part of the sliver were held between the finger and thumb of one hand, and another part, at an inch or two distant, being held in the other hand. Then by drawing the two hands asunder to the extent of four inches, it is evident two inches in length of the cotton sliver would be extended or drawn out to four inches. In like manner, the first pair of rollers through which the sliver passes, are pressed together with a sufficient weight to hold the cotton firmly between them. The second pair of rollers are situated at one or two inches distant, and are made by the wheel-work to revolve more swiftly than the first. The difference of velocity, however, is but small, though the consequence is, that the sliver will be lengthened in the same

proportion; for the second rollers take up the cotton much faster than the first pair will deliver it out: it must, therefore, be either forcibly pulled through between the first rollers, or it must be stretched a little, by the fibres slipping among each other, or it must break. When the extension is small, the only effect of it is merely to begin to draw the fibres (which are at present lying in every possible direction) into a straight and parallel position, which is most favourable for the subsequent extensions. The drawing frame contains a third, and some of them a fourth pair of rollers, by which the sliver undergoes a second or third draught; but the combined effect of all these drawings is generally to extend the sliver to four times the length it was when first put to the machine. But as this would reduce the sliver to one-fourth of the size, which is not intended in this stage of the process, four ends or slivers are introduced between the rollers together, and being drawn into one, which is four times the length, it will of course be of the same size as any one of the four which is put in. This drawing process is repeated three or four times, and the alteration it makes in the cotton is to equalize the size of the sliver, on the same principle as before described of the breaking card, *viz.* by repeatedly combining four together, and drawing them into one: it also disposes the fibres longitudinally and in the most perfect state of parallelism. The operation of carding effects this in a certain degree; yet the fibres, though parallel, are not straight, but many of them doubled, as may easily be supposed, from the teeth of the cards catching the fibres sometimes in the middle, which become hooked or fastened upon them.

Though the general arrangement of the fibres of a sliver from the finishing card is longitudinal, yet they are doubled, bent, and interlaced in such a way, as to render the operation we are now speaking of absolutely necessary.

When the cardings have been passed four or five times through the drawing frame, every fibre is stretched out at full length, and disposed in the most even and regular direction, so that each fibre will, when twisted into a thread, take its proper bearing, in consequence of every one being straightened and having the same tension.

The sliver in this state presents a most beautiful appearance, being so extremely regular in its size, and all the fibres drawn so straight, that it bears a fine glossy or silky appearance. It is upon this sliver or ribband of cotton wool that the operation of spinning begins. The general effect of the spinning process is, to draw out this massive sliver, and to twist it as it is drawn out: but this is not to be done by the fingers, pulling out as many fibres of the cotton at once as are necessary for composing a thread of the intended fineness, and continuing this manipulation regularly across the whole end of the ribband, and thus, as it were, nibbling the whole of it away. The fingers must be directed for this purpose by an attentive eye; but in performing this by machinery, the whole ribband must be drawn out together and twisted as it is drawn. This requires great art and very delicate management: it cannot be done at once, that is, the cotton roll cannot be first stretched, or drawn out to the length that is ultimately produced, from the tenth of an inch of the sliver, and then twisted. There is not cohesion enough for this purpose, it would only break off a bit of the sliver, and could make no further use of it; for the fibres of cotton are very little implicated among each other in the sliver, because the operation of carding and drawing has laid them all parallel in the sliver; and though compressed a little, by its contraction in the card from a fleece of twenty inches to a ribband of two, and afterwards com-

pressed between the rollers of the drawing frame, yet they cohere so slightly, that a few fibres may be drawn out, without bringing many others along with them. For these reasons, the whole thickness and breadth of two or three inches are stretched to a very minute quantity, and then a very slight degree of twist is given it, *viz.* about two or three turns in the inch, so that it shall now compose an extremely soft and spongy cylinder, which cannot be called a thread or cord, because it has scarcely any firmness, and is merely rounder or slenderer than before, being stretched to about four times the former length. This is called *roving*, and the operation is performed in the

Roving Frame.—This machine is constructed in a great variety of forms, but all of them have the same object in view, *viz.* to draw out the sliver, so as to reduce it from a large band to a coarse and loose thread: but as this extension would render it so extremely tender, that it would scarcely hang together in passing through the succeeding machines, the roving frame, immediately after having drawn and extended it to the intended size by rollers, operating in the same manner as the rollers of the drawing frame, gives it a very slight twist, as before mentioned, and this loose thread, which is called the roving, is the first rudiment of a thread. Although it is extremely tender, and will not carry a weight of two ounces, it is much more cohesive than before, because the twist given to it makes all the longitudinal fibres bind each other together, and compress those which lie athwart; therefore it will require twice the force to pull out a fibre from among the rest, but still not near enough to break it. In drawing a single fibre others are drawn out along with it, and if we take hold of the whole assemblage in two places, about an inch or two asunder, we shall find that we may draw it to near twice its length, without any risk of its separating in any intermediate part, or becoming much smaller in one part than another. It seems to yield equally over all parts.

Our readers will now perceive, that these processes will ensure all that is wanted, and prepare a roving that is uniform, soft, and still very extensible: in short, fit for undergoing the last treatment of spinning, by which it is made a fine and firm yarn.

It is evident that the roving produced by these operations must be exceedingly uniform. The uniformity really produced exceeds all expectation; for even although there be some small inequalities in the carded fleece, yet if these are not matted clots which the card could not equalize, but only consist of a little more thickness of cotton in some places than in others, this inequality will first be diminished by the lapping of the fleece in the breaking card; and when such a part of the sliver comes to the first roller of the drawing frame, it will be rather more stretched by the second than a thin part would be. That this may be done with greater certainty, the weights of the first rollers are made very small, so that the middle part of the sliver can be drawn through, while the outer parts remain fast held.

Such is the state of the roving as prepared by the roving frame. All the preceding processes are to be considered as the preparations: and the operation of spinning is not yet begun. These preparations are the most tedious, and require more attendance and hand-labour than any subsequent part of the process. For the slivers from which the rovings are made are so light and bulky, that a few yards only can be piled up in the cans set to receive them from the carding and drawing: a person must therefore attend and watch each roller of the drawing and roving frames, to join fresh slivers as they are expended. It is also the most important depart-

ment in the manufacture; for as every inch will meet with precisely the same drawing and same twisting in the subsequent parts of the process, therefore every inequality and fault of the sliver, indeed of the fleece as it quits the finishing card, will continue through the whole manufacture, in a greater or lesser degree, being only diminished, not corrected, by the drawing, doubling, &c. The spinning of cotton-yarn now divides itself into two branches. The first performed by what were called jennies, when worked by the hand, but since they are moved by the power of a mill, they are called mules; the manner of action resembles the ancient spinning with distaff and spindle. The second method, called spinning of *twist*, or *water-spinning*, because it was the first spinning performed by a water-wheel, is in imitation of the spinning with the fly-wheel, or jack and flyer. The two methods differ in the same manner, as the old wool or cotton-wheel differs from the spinning with the flax-wheel. Mr. Arkwright's chief invention, the substitution of the machinery for the immediate work of the human finger, was at first only applied to the manufacture of twist, or water-spinning. We shall, therefore, first direct our attention to this.

The *water-spinning* process is little more than a repetition of that gone through in making the first slivers or rovings, which are formed on bobbins, either by the roving frame, or are afterwards bound on bobbins by the hand. These bobbins are set on the back part of the

Spinning-frame, in which the roving is drawn, and extended to any required degree of fineness; and the proper twist being given to it, forms it to the required thread. The spinning-frame is provided with systems of rollers, in the manner of the drawing-frame, through which the roving passes, and is drawn out according to the size of the thread which is required to be spun, which varies from four to seventeen times; and it is then twisted more or less, as the thread is required to be hard or soft: therefore, the spinning process scarcely differs from the roving, except in the twist that is given it, after the last stretching, in its length. This is much greater than the roving, being intended to give the yarn hardness and firmness, so that it will afterwards break rather than stretch any more. The perfection of the ultimate thread or yarn depends, in a great measure, on the extreme softness of the roving; for it is this only which makes it susceptible of an equable stretching, all the fibres yielding and separating alike: and this property will be greatly influenced by the quantity of twist given by the roving-frame. For these points no very distinct rule can be given: it varies in different mills, and with different species of cotton wool, as may be easily imagined. The immediate mechanism, or manipulation, must be skilfully accommodated to the nature of that friction which the fibres of cotton exert on each other, enabling one of them to pull others along with it. This is greatly aided by the contorted curled form of a cotton fibre, and a considerable degree of elasticity which it possesses. In this respect it greatly resembles woollen fibres, and differs exceedingly from those of flax; and it is for this reason that it is so extremely difficult to spin flax in this way: its fibres become lank, and take any shape by the slightest compression, especially when damp in the slightest degree. But beside this, the surface of a cotton fibre has a harshness or roughness, which greatly augments their mutual friction. This probably is the reason why it is so unfit for tents, and other dressings for wounds, and is refused by the surgeons even in the meanest hospitals. But its harshness and elasticity fit it admirably for the manufacture of yarn. Even the shortness of the fibre is favourable; and the manufacture would be very difficult, if the fibre were thrice as long as it generally is. If it be just so long that, in the

finished thread, a fibre will rather break than come out from among the rest, it is plain that no additional length can make the yarn any stronger, with the same degree of compression by twining. A long fibre will indeed give the same firmness of adherence, with a smaller compression by twining. This would be an advantage in any other yarn; but in cotton, the compression is already as slight as can be allowed: were it less, it would become woolly and rough by the smallest usage; and it is already too much disposed to teaze out. Now, suppose the fibres much longer, some of them may chance to be stretched along the sliver through their whole length. If the sliver is pulled in opposite directions, by pinching it at each end of such long fibre, it is plain that it will not stretch till this fibre be broken up, or drawn out; and that while it is in its extended state, it is acting on the other fibres in a very unequable manner, according to their positions, and renders the whole apt to separate and draw more irregularly. This is one great obstacle to the spinning of flax by similar machinery.

Mule-spinning.—A great proportion of the cotton is spun in the mule instead of the water-frame. The preparation it undergoes for either method is the same; at least the processes are similar, except that the quantities of draft, and some other particulars, may be varied in the preparation of the cotton which is to be thus spun in this machine, which is called a mule, either because it is a kind of machine which might easily be turned by a mule, or more probably because it is a sort of mongrel, partaking of the nature of both drawing and spinning, or uniting the action of both the roller and spindle. It consists of three sets of fluted brass rollers, the flutes of which turn into each other. The first set goes faster than the second, and the second faster than the third; between which, when the sliver of carded cotton enters, it is a little lengthened out between the first and second, and farther still between the second and third; after passing which, it is slightly twisted by the rapid circular motion of the spindle. This has the same effect as the spinning-frame; but the quantity of draft between the rollers, or extension of the sliver, is not, like the water-frame, to the full extent which the thread is intended to be. The remainder of the stretching is performed in this manner: the spindles of the mule, which give the twist to the thread, are fitted in a frame, so that they can be moved backward and forward, in a straight line, to and from the rollers; a certain length of the roving being therefore given out by the rollers, the spindles are removed backward to take it up as fast as it comes, and in this motion they twist it slightly: at the same time, but after a certain quantity of the roving, a yard for instance, has been given out by the rollers, their motion ceases; but the spindle continues to recede from them, another half yard for instance, continuing to twist the thread all the while. By these means, it is evident that the thread will be stretched from a yard to a yard and half in length: by this contrivance, the cotton will bear a greater degree of extension than any other, because it is constantly twisted at the same time that it is extended in length.

The invention of mules forms quite an epoch in the history of the cotton trade. A vast improvement was made, about 35 years ago, by the introduction of the spinning jennies, by which from twenty to forty spindles were turned at a time. The spindles were the same as the mule, and had the same motion; but this machine was not provided with rollers to draw out the cotton, previous to twisting, merely depending upon the stretching, to give it the proper extension requisite to form the roving into a thread. But the combination of the jenny with Sir Richard Arkwright's invention of drawing, by rollers, forms a method superior to both, at

least for fine goods. The method of stretching gives the means, as we have before mentioned, of very great extension; but if this be carried so far as to draw out the coarse loose roving to a fine thread, there will be great danger of its drawing irregularly, that is, more in one place than another. In the original method by the jenny, the rovings were prepared by the hand-wheel: they were loose, coarse, untwisted threads, partaking somewhat of the nature of cardings, though approaching in some degree to spun twist. They were obliged to be prepared by the hand-wheel, because the cardings, which were prepared by hand-cards, were in detached pieces of a certain length, and regularly tapering towards each end: the joining of these together, in such a manner as to produce an equal and regular roving, required a care and attention which could not be effected by machinery.

The combination of sir R. Arkwright's system of preparation with the jenny produced the mule, which, without the defects of its original, spins in the most expeditious and perfect manner. The advantage of this mode of preparing the threads over that of the jenny is, that the fibres of the cotton are all laid longitudinally, and nearly in as small number as is wanted, before they are begun to be much twisted; by which means, threads of any required fineness are made much stronger than they were from rovings, made upon the spindle of the hand-wheel spun in the jenny, which twisted them too much in the first instance; and in the subsequent extension or stretching, by the removal of the spindle, for rendering them finer, many of the fibres were necessarily broken. On one of these mules 240 threads are often spun at once; and two of them may be managed by one woman, with a child to tie the threads which may occasionally break.

It is needless, as the jenny has become an obsolete machine in the cotton manufacture, to enter into any further details, particularly as the mechanism so nearly resembles the jenny still used in the WOOLLEN manufacture. See that article.

The reader moderately acquainted with mechanics, cannot but perceive that by each of the operations now described, the cotton-wool is prepared, and drawn into a fine strong thread, by repeatedly drawing the spiler till its fibres become straight, then reducing it in the roving frame to a coarse thread, and by a slight twist giving it sufficient strength to bear such an extension as will reduce it to the size intended, and then it is immediately twisted into a hard thread. All these processes are only a substitute for a single pull of the finger and thumb of the spinner, which she accommodates precisely to the peculiar condition of the lock of wool which she touches at the moment: she can follow this through all its irregularities, and, perhaps, no two succeeding plucks are alike. But when we cannot give this momentary attention to every minute portion, we must be careful to introduce the roving in a state of perfect uniformity, and then every inch being treated in the same manner, the final result will be equable, and the yarn will be uniform.

The thread being now finished, either by the water-frame or mule, it is carried to the

Reel, by which it is taken off the bobbins of the spinning frame, or the cops of the mule, and formed into hanks. The hank is a measure in cotton trade, composed of seven *leys*, each of 120 yards in length. The reel or frame round which the thread is wound is one yard and a half in circumference, and at every 80 turns (or *bouts*) which it makes, the 80 turns of the thread are tied together to keep them separate, and this measures out 120 yards, which is called a

ley: but the thread is not cut at the ley, it is continued to be wound on the reel, till seven such leys, or 840 yards, are reeled: it is then cut and called a hank, which is tied up.

The different sizes of cotton yarn, or thread, are denominated according to the number of these hanks which will weigh a pound. The hank of 840 yards in length is the measure used in all English cotton-mills, and thus affords a very accurate and convenient standard for the size of the cotton. The number is ascertained by weighing each individual hank in a little *weighing instrument*, which shews by an index what number of such hanks will weigh a pound. Each hank being twisted up is suspended on the hook of this instrument, and the number being ascertained, the hank is put on a proper shelf till they are all sorted. Then by a table on purpose it is seen how many hanks of any number will weigh 10 lbs. and this number being counted out from any one shelf, is packed up in the *bundling press*, and tied in papers, marked, and sent away for market. Sometimes, the cotton intended for weaving is warped in the warping-mill before it is sent away from the mill: this saves the weaver an immense deal of trouble.

Some of the twist is wound on quills for the shuttle; and others, again, are formed into hanks, some of which are tightly bound round at certain intervals previous to their being dyed, in order to prevent the parts so tied from taking the colour. This is done that the threads may be disposed to warp in the weaving loom, so as to produce the clouds which are seen in various species of the cotton goods, especially ginghams.

Some of the cotton thread is dyed in the hank, and other cotton which is intended for sewing, knitting, &c. or to weave fine goods, is bleached; and because in this process, or in dyeing, some shrinking takes place, it is wound from the hanks upon bobbins again by the *winding machine*, and from these bobbins it is again reeled into hanks, in which it is packed up and sent to market: other cotton thread for sewing, mending, and domestic use, is wound into balls of a figure resembling a cask, and the many interfections of the thread are so managed as to produce a very beautiful appearance.

The denominations of the quality of the different kinds of cotton threads are chiefly divided into *yarn* and *twist*, and this is called *mule twist*, or *water twist*, as it is spun either in the mule or water-frame. That thread which is denominated *water-twist*, is used for weaving calicoes, &c. It is spun hard, that is, with a great deal of twist, so that it forms a strong hard thread. It is manufactured of all numbers, from 10 to 60 hanks *per pound*.

The *mule-twist* is used for weaving muslins and the finest cotton goods. The essential differences between this and the water-twist are, that the mule produces much finer articles than are attempted on the water-frame, at the same time it makes a softer thread. As it requires much less power to work it than the water-frame, the manufacturer spins every thing in the mule which will admit of it; but it will only produce the soft kinds of thread. The mule will spin all numbers, from the lowest to 150 or 170 hanks *per lb*. The trade of Manchester is chiefly mule spinning, whilst the water-twist is mostly spun in the country by water-mills, because the great power it requires is too expensive for steam-engines, at least the water-mills have the advantage, being usually in situations where they have their power at a less expence than those turned by steam-engines.

Stocking yarn is spun softer than twist, and two threads are afterwards doubled together in the doubling machine, and then slightly twisted round each other in the twisting ma-

chine. Sometimes one of the threads is dyed black, or blue, before the twisting, and then it produces a speckled thread, which is called one-thread white. This yarn is chiefly used in the stocking-frame; it is spun in all numbers, from 10 hanks in the pound up to 60. The threads of stocking yarn are but slightly twisted, so that its composition of two threads is always distinctly visible.

Sewing cotton is made either from twist or cotton yarn doubled, and twisted very hard together by passing it a second time through the spinning frame, so as to form a strong thread, which may be compared to a small rope, as the two threads make one very compact and defined thread.

Mending cotton is the same as sewing, but of less twist: indeed the distinction is trifling.

Knitting cotton is twisted with two or three threads, but not so hard twisted as sewing cotton, though it is harder than mending. This cotton is frequently bleached after it is twisted.

Candlewick cotton is a very loose coarse thread, made from the cheapest and most inferior kind of cotton: being only intended for the wick of candles, no great care is used in the manufacturing. A great deal of candlewick is made from tow which is bleached, and makes an article something like the cotton in appearance, but by no means equal to it in quality. This is known by the cant term of *bump*, and many large mills are employed in spinning it. The cotton candlewick is known by the name of *Turkey*, which is made from Smyrna or other cheap inferior kinds of cotton. It is spun generally about 10½ to 11 hanks *per lb.*, and sent off to market wound up in large balls. Oxford candlewick is made from inferior cotton, about seven hanks to the pound. Wiltshire candlewick is made from waste cotton, about No. 7. These articles are spun without the care requisite for yarn or twist: they are usually spun by mules, and in some mills for coarse goods they do not take the trouble to form them into rovings at all, but spin the candlewick at once from the slivers, as prepared by the drawing-frame.

To pursue the progress of the cotton after being spun into twist, we must remove from the cotton-mill to the cottage of the weaver. Here, the warp being fixed in the loom, or, in the language of the weaver, warped, it is divided to give passage to the weft in the shuttle, either by two, three, or more treadles; or if the pattern or course of changes in the order of raising and depressing the threads of the warp be various, so that the weaver could not manage the requisite number of treadles, it is done by a great number of strings which pass over pulleys above the loom, and are drawn one after another by a little boy, above whose head they are disposed in two rows by the sides and between two looms. These looms are, therefore, called *draw-boys*. These boys will shortly be set aside for machinery, which is rapidly introducing a substitute. For the formation of sprigs, &c. of various colours, there are often as many shuttles as colours, or a number of little swivel looms, such as they use for the weaving of tapes, introduced occasionally, as many as there are sprigs in the breadth of a piece. Quiltings appear to be two distinct cloths, tied as it were together by ditches, which go through both cloths, and in some cases, as in bed-quilts, there is a shuttle which throws in a quantity of coarsely spun cotton, to serve as a kind of wadding. The counterpanes are woven with two shuttles, one containing a much coarser weft than the other; the coarser of the threads is picked up at intervals with an iron pin, rather hooked at the point, so as to form knobs disposed in a sort of pattern.

When the goods are come from the loom, most sorts of

them, previously to being bleached, are fired or dressed, by being drawn, and that not very quickly, over red-hot cylinders of iron, by which the superfluous nap is burnt off. To see such an operation performed upon so combustible a substance, naturally fills a stranger with the utmost concern and astonishment. They are then washed in a wheel with soap and water, and having been well scoured with an alkaline lixivium, are dipped in the oxygenated muriatic acid, diluted to its proper strength. These preparations are repeated alternately, till the goods have attained the requisite whiteness; and between each dipping they are laid out upon the ground, and exposed to the action of the sun and air. When completely bleached, they are either smoothed upon long tables with smoothing irons, or calendered; that is, stretched and pressed between a course of rollers, by which they acquire a fine gloss. Calicoes are printed exactly in the same way as the kerseymeres in Yorkshire, but the works are usually upon a much larger scale. See PRINTING.

Thickets, corduroys, velveteens, &c. are cut upon long tables, with a knife of a construction somewhat like the sting of a wasp, terminating in a very sharp point, defended on each side by a sort of sheath. This point is introduced under the upper course of threads which are intended to be cut, and with great ease carried forward the whole length of the table.

The rapid increase of the cotton trade appears to have been owing, in a great measure, to the more liberal introduction of machinery into every part of it, than into any other of our staple manufactures. The utility and policy of employing machines to shorten labour, have been a subject which has exercised the pens of many ingenious writers, while their introduction into almost every branch of manufacture has been attended in the outset with much riot and disorder. They are undoubtedly wonderful productions of human genius, the progressive exertions of which neither can nor ought to be stopped; they enable a manufacturer to produce a better article than can be made by the hand, in consequence of the uniformity and certainty of their operations, and at a much lower price, in consequence of the vast quantities of goods they are capable of performing. They thus support the credit of our manufactures abroad, and enable us under the vast load of taxes, and consequent increase in the price of every necessary of life, to meet our foreign competitors with advantage at market. They can even allow the goods to furnish in their passage a considerable revenue to government. And although they do, undoubtedly, on their first introduction, throw some persons out of employ, by changing the nature and course of business, they almost immediately make up for the inconvenience by astonishingly multiplying the absolute quantity of employment. If they have taken away work from carders and spinners, they have returned it them back tenfold, as winders, warpers, weavers, dressers, dyers, bleachers, printers, &c.

It is this machinery which we have now to explain. An extensive cotton mill contains most interesting specimens of human ingenuity and resource, and shews in a striking manner what may be done, when the talents of a great number of individuals are directed to one common object, and where the most perfect is of such importance (from the frequent repetition of it which is necessary) as to become worthy the consideration of the manufacturer to devise machinery for accomplishing it in a better or cheaper manner. There is, in the cotton trade, such a spirit of improvement, that they have, as a body, less prejudice in favour of old established customs than perhaps any other class of this is doubtless a reason of the great perfection of their art,

as they have made trials of new ideas, without those years of reflection which men in other trades require before they will venture to embark in any new improvement, though ever so promising and favourable in appearance.

Our readers, who are unacquainted with the subject, will now by this sketch have obtained such a general idea of the cotton manufacture, as will enable them to comprehend the technical terms which are necessary to be used in the subsequent explanation of the machinery, and those references which must sometimes be made from one process to another. A large cotton mill is generally a building of five or six stories high: the two lowest are usually for the spinning frames, if they are for water twist, because of the great weight and vibration caused by these machines. The third and fourth floors contain the carding, drawing, and roving machines. The fifth story is appropriated to the reeling, doubling, twisting, and other operations performed on the finished thread. The sixth, which is usually in the roof, is for the batting machine, or opening machine, and for the cotton pickers, who for a large mill are very numerous. This last is not always so occupied, many manufacturers thinking it better to have out-buildings for these parts of the process, and only to have such parts in the mill as require the aid of the large water-wheel, or steam-engine, which turns the whole mill. If the mule is used for spinning instead of the water frame, then the cards are usually put below, because they are then the heaviest and most powerful machinery.

The first machine we shall describe is the *Batting machine*. Plate II. *Cotton Manufacture*, *fig. 1*, is an elevation sideways, and *fig. 2*, an elevation endways, the frame being in both described by dotted lines, that it may not obscure the mechanism: *figs. 3, 4, and 5*, are detached parts of the machine. The moving power is communicated by the mill to an horizontal axis, on which the fly-wheel, *C*, is fixed, to regulate the motion. On this axis four cranks are formed, as shewn at *i, i, i, i*, making equal or right angles with each other; and connecting rods, *i, b*, being extended from these cranks to the lower ends of the levers *g, g*, which are moveable on the centres *f*, cause them to vibrate alternately when the cranks are turned. There are four of these levers situated on each side of the machine, all the four on each side having one common centre at *f*. Each crank on the main spindle has two connecting rods upon it, to actuate two different levers; but which being situated on opposite sides of the machine, of course receive their motion alternately: at the upper ends, *e, e*, of the levers, which, as the figure shews, are much longer than the lower ends, that is, the centre of motion, *f*, is placed considerably beneath the middle of the levers. At the upper ends, *e, e*, of the levers joints are formed, by which they are connected with rods, *x*: these perform the batting, by striking in the manner we shall describe upon the platform *A*, where the cotton is spread. This platform is formed of a long cord, which is repeatedly passed over two rollers, one of which is shewn at *m*, and the other is at the opposite end of the machine: the cord passing round from one of these to the other twenty or thirty times, and having all the turns made parallel to each other, at about an inch asunder, it forms an horizontal platform for the support of the cotton; but to fill up the interstices between these ropes another stationary set is placed. These are strained between two fixed beams of the frame, as shewn in *fig. 4*, which is a plan (and a section is situated immediately beneath it.) The roller *m*, *fig. 1*, is kept in continual rotation by a train of toothed wheels, marked *k k k k l*, which communicate the motion by a pinion on the main axis from one to another,

and lastly to the roller by means of a contrate wheel *l*, in which a pinion acts. By these means the endless rope, which extends from one roller to the other, and forms one-half of the platform for the cotton, is in constant motion, and the cotton which is laid upon it at one end traverses slowly to the other, receiving in its passage the blows of the rods *x*, which strike upon it alternately. Their action is produced in this manner; the levers, *g, g*, are forked at the upper ends, as shewn in *fig. 5*, so as to afford a sufficient length of bearing for a short axis *3, 4*, on which the rod *x* moves. The small dotted circle *3*, in this figure, represents the place where the rod unites with the axis, or rather where a small iron tube proceeds from the axis; and in the end of this the wooden rod, *x*, is inserted, and held fast by means of a screw clamp, or loop, surrounding the end of the tube, and compressing it upon the rod, one side of the tube being split down to admit of this compression. Upon the same axis as the rod *x* are fixed two small pulleys *1, 2*, to each of which a strap is attached, and, after making a turn round their respective pulleys, these are conducted away to a fixed part of the framing, in the manner shewn in *fig. 1*. These straps are of such a length, as to hang loose during a greater part of the time; but when, by the motion of the top of the levers *g, g*, *fig. 1*, they come to their tension, they operate upon the pulleys *1* or *2*, *fig. 5*, and turn them half round with their axis, at the same time turning over the rods *x, x*. This motion is more clearly explained by *fig. 3*, which will, at the first view, be seen to be only a detached section of the parts already described in *fig. 1*. *A* represents one of the vertical levers (*g, fig. 1.*), and *F* its centre of motion, upon which it traverses from the position *A*, to that represented by the dotted lines *B*, by the action of the crank rod joined to the lower end of it, as before described; therefore the two positions, *A, B*, are to be considered as the extremes of its movement. *E* represents the pulleys which are fixed on the axis of the batting rod *b*, the two appearing as one in this view. One of the straps of these pulleys is fastened by one end at *n* to a fixed part of the frame, and the other end is made fast to the pulley at *o*. The other strap has one of its ends fastened to the pulley at *k*, while the opposite end is attached at *i* to a lever *im*, whose centre, *G*, is stationary. The lower end, *m*, of the lever has a strap attached to it, which proceeds to the lever *A*, and is made fast thereto at *l*. The operation of this construction may be thus explained: in the position *B*, the strap, *if*, (answering to *ik* in the other position) hangs slack, as in the figure, while the other strap, *rn*, has come to its tension, and has turned over the batting rod to the position *g*. Now, suppose by the action of the crank rod the lever is moved towards the position *A*, it proceeds for some distance with the rod *g*, remaining horizontal, and merely drawing along endways; but when it is advanced rather more than half way, the straps, *lm* and *ik*, come to their tension: the former pulls the lower end, *m*, of the lever, *mi*, after it, and, of course, the upper end, *i*, at the same time moving in an opposite direction, draws the strap, *ik*, with it, turning the pulley *E*, and the batting rod attached to it, over into the position *b*, and striking on the cotton spread on the platform. This motion is performed almost instantaneously, because, the strap *ik* being drawn in one direction, whilst the centre of the pulley it is fastened to moves in an opposite direction, these motions cause the pulley *E*, and the batting rod which is attached to it, to turn over with a double velocity, to what it would have had if simply actuated by the motion of the lever *A*; so that this rapid motion causes the batting rod to strike with an exceedingly smart stroke upon the cotton laid upon the platform. In

returning back again to the position B, which the crank causes it to do very shortly after having made the stroke, it proceeds, as before mentioned, to beyond the half way, with the straps hanging slack and having no action; but when it has passed rather more than half way, the strap, *n*, becomes tight, and turns the pulley over, bringing the batting rod to the position *g*, ready to make another stroke; but in turning it over to this position, the rod does not move with such velocity as to strike a blow upon the cushion *d*, *fig. 1*, which is placed to receive it, because the strap, *f*, *n*, is fixed to a stationary point *n*, instead of having a motion in the opposite direction to the lever, as the other strap *l*, *k*, which caused the stroke upon the cotton. In *fig. 1*, the frame is marked B, and *o*, *o*, represent the levers *i*, C, *m*, *fig. 3*. The lever *g*, *fig. 1*, which is nearly in a vertical position, appears to have two of the rods *n* proceeding from it in opposite directions. This appearance is occasioned by there being two levers in that position exactly behind each other, though they are moving in opposite directions, therefore one of the rods, *n*, remains upon the cotton at A: the other, which belongs to the lever concealed behind, is represented as just rising from the cushion *d*. *Fig. 2*, is an edge view of the machine, where A represents the strap which communicates motion to the machine by means of two pulleys, called the live and dead pulley, from the circumstance of one pulley being fitted loose, so as to slip round freely upon the axis, whilst the other pulley is fixed fast upon the axis: therefore, when the endless strap is shifted upon the loose or dead pulley, it slips round without communicating any motion to the machine; but when it is shifted on the other pulley, the machine immediately commences its motion. E represents the fly-wheel on the opposite end of the axis, and B, B, B, B, are the four cranks which actuate the levers C, C, C, C: *f* is one of the rollers on which the endless cord or platform, D, is wound, and it extends from this to a similar roller on which a wheel, *g*, is fixed; then returning again to the roller, *f*, and after having made in this manner more than twenty turns round the two rollers, the ends are strained tight and spliced together, so that it appears like *fig. 4*, forming a platform on which the cotton lies, and is regularly carried from *f* to *g* by the motion given to the roller *f* through the cog-wheel *e*, and the other train of wheel-work which communicates with the main axis, as before described. At the sides of the platform two boards are fixed which form a trough, and prevent the cotton getting off sideways. The batting rods strike down through openings or notches *d*, *d*, *d*, *d*, cut in these boards. The dotted lines represent other notches to admit the batting rods on the opposite side of the machine, which, as this figure shews, are not precisely opposite, but the rods on one side strike in the interval between those of the others. The cotton, after passing along with the moving cords through the machine, is thrown off, and falls upon a table *i*, *fig. 2*, which is covered with an endless canvas cloth, and is strained over two rollers *b*, *k*, which are kept in constant motion by an endless band passing round the wheels *b* and *g*. By this motion of the cloth the cotton is conveyed away as fast as the batting machine finishes it, and is taken off this table by women, who discharge it into baskets, in which it is conveyed to the picking room.

The opening Machine, or Devil.—This machine comes next to be described, being used for similar purposes as the batting-machine, though it is not to be considered as one of the same series, being used for the coarser sort of cotton in the same stage as the batting engine is used for the finer sorts. *Plate III.* contains drawings of one of these machines, in which *fig. 1*, is a plan, and *fig. 2*, a section. In

either of these A A represents a cylinder, put in rapid motion by an endless band passing round the pulley R. This cylinder has a great number of teeth fixed into its periphery, and the hood or arch, E E E E, contains a set of similar teeth or spikes fixed within it. This casing consists of a number of parallel bars or lags, one of which is shewn in perspective in *fig. 5*: these are supported by an iron semicircle B B, *fig. 3*, also erected on each side

P P, projecting from it, and every lag has a notch, or cleft, cut at each end, by which they are hung on these pins, forming a very simple manner of fixing the lags; but they can be easily removed when required, to clear the machine from the flue and impurities which it gets out of the cotton. In front of the cylinder a pair of feeling rollers, *d*, *d*, are fixed, through which the cotton passes to the machine: these rollers are fluted and placed immediately above each other, as shewn in *fig. 2*; then a heavy weight L, being suspended from the pivots of the upper roller, causes them to press together with a sufficient force to draw cotton in between them, and the flutes or indentations of the two rollers mutually locking into each other, they take the cotton more certainly. The lower roller is turned round by means of a bevelled wheel *l*, *fig. 1*, fixed on its spindle, which receives its motion from a similar bevelled wheel *k*, fixed on the extreme end of a spindle I, fixed perpendicularly to the axis of the main cylinder, and receiving its motion therefrom by a wheel *b*, which is turned by an endless screw *g*, cut upon the extremity of the spindle of the great cylinder.

The cotton is spread upon an endless revolving cloth, which is strained between two rollers, *a*, *b*, and is in constant motion, in the direction of the arrow in *fig. 2*. This motion is communicated to the roller, *a*, by means of equal cog-wheels *d*, *d*, which are connected by an intermediate toothed wheel, as shewn in *fig. 2*; M S is a grating, or frame of brads wire (shewn separate in *fig. 4*.) which is extended beneath the cylinder, and against this the cotton is urged by the action of the teeth of the cylinder, and the dirt, dust, and flue, escape through it. It should be observed, that the frame for the machine is closely boarded up on all sides, to keep in the dust and flue which is separated from the cotton. *Fig. 5*, shews the form of one of the lags, and the manner in which the teeth are disposed in it, so that the teeth in the several rows fall opposite the spaces between the teeth of the others: at *i* is a small slip of sheet iron, which stands up perpendicular to the face of the lag like the spikes, and is supported by a kind of wedge, or prop of wood, as seen in the section of the machine, *fig. 2*. These slips of iron run across the whole length: the teeth on the cylinder are disposed in a similar manner, and are provided with a similar iron plate. Their use is to retain the cotton which is worked in the machine from passing through too quickly, and escaping without being sufficiently worked by the teeth. The cotton is spread evenly upon the cloth *b*, *d*, which being in constant motion towards the cylinder, carries the cotton along upon it, and delivers it between the two rollers *d*, *d*: these give it regularly to the cylinder, which is rapidly revolving in the direction of the arrow near A: its teeth take the cotton, and carry it round between the cylinder and the hood, working it between them, to open and unravel every knot or tuft of cotton, part of which gets formed by the action of the cylinder into a small roll at every one of the iron plates *i*, and this roll, by the motion of the cylinder, keeps revolving slowly round, so that every part of its circumference is successively subjected to the action of the teeth of the cylinder

as they pass by them. The plates upon the cylinder act in a similar manner, and when the cotton is thrown out finished at M, upon the floor immediately beneath the feet cloth, it has been opened in every part, so as to completely disentangle it, and the dust, cotton seeds, or any other extraneous matter, drops out through the wire grating, S M, upon the floor.

The opening machines used in some of the most improved mills, are provided with two cylinders revolving against each other, so that they resemble two of these machines put together, by which means the cotton is more completely worked in passing through them. The cylinders have then none of the plates fixed upon them, because they are unnecessary, and the spikes or teeth are arranged in a spiral line round the circumference of each cylinder, so that they do not in their motion fall behind each other, and therefore work and open the cotton more effectually. Another great improvement in this double cylinder machine, is the addition of a flue or trunk, which proceeds horizontally from the opening or mouth M, where the cotton is delivered, for a considerable distance, and in the bottom of this is a revolving cloth, which receives the cotton as it is thrown out, and conveys it away to the end of the room containing the machine. Here it falls out into a basket, in which it is conveyed away to the picking room. The flue or trunk at this point rises up, and leads into a chamber of considerable size, and from this returns by a small trunk to the back of the machine. The operation of this trunk is, that the wind raised by the rapid motion of the cylinders proceeds along this narrow trunk with a considerable velocity, and blowing along over the surface of the cotton, which is traversing slowly along with the endless cloth in the bottom of the trunk, it carries away the flue or small cotton with the stream into the large chamber above-mentioned. Here, in consequence of the large area which the air has to pass through, the current is very slow, and the flue subsides quietly on the floor of it, from which it may be taken up in considerable quantities every week, and is a valuable article for making candlewick, or to mix with inferior cottons for that purpose; whereas, if suffered to fly about in the rooms, as in the machine delineated, it does great injury to the work people, for this flue is taken into the lungs by the respiration, causing asthma, and pulmonary complaints: but in the improved machine, this flue is preserved for useful purposes.

The next machine, in the order of the cotton manufacture, is the *Carding machine*. This is shewn in *Plate IV.*, where *fig. 1.* is a plan, *fig. 2.* a section, *fig. 3.* an elevation, and *fig. 4.* various parts to explain the action of this machine. It will not be amiss first to give a short idea of the nature of the operation to be performed by the machine. The card may be compared to a brush made with wires instead of hairs, stuck through a sheet of leather; the wires not being perpendicular to the plane, but all inclined one way in a certain angle. See *fig. 4.* of this plate, where D, C, are these sheets of leather for a pair of cards, and A, A, or B, B, represent the teeth or card-wires respectively belonging to each. Beneath is a view of one wire, insulated, shewing the two teeth, with their bend in the flank, or what is called knee-bend, by which they are inclined to the leather in the manner before mentioned. Now we may conceive that, cotton being stuck upon the teeth of one of these cards, another may be applied to it, and combed or scraped in such a direction as to strike the cotton inwards upon the teeth, rather than tend to draw it out. The consequence of a repetition of the strokes of the empty card, in this direction upon the full one, is a more equal distribution of the cotton upon the surface of the card-teeth; and in doing this, the fibres are combed and laid straight. Then

if one card be drawn in an opposite direction over the other, it will, in consequence of the inclination of its wires, take the whole of the cotton out of the card, whose inclination is the contrary way. In this mode, the operation was formerly conducted by sheets of cards nailed upon boards, which were worked together by hand. To explain how the carding machine imitates this process, we must return to the figures, in which A A is a large cylinder, turned rapidly round by an endless strap on the pulley R. The surface of the cylinder is covered with cards, the sheets of leather for which are glued or nailed on in stripes or sheets parallel with its axis, and disposed in such a direction, that when it revolves in the direction of the arrow, the teeth upon it go with their points forward, so that if a lock of cotton was held against them, it would be drawn inwards upon the teeth. The cylinder revolves under an arch C C, lined with the same kinds of cards as shewn in *fig. 2*; the teeth disposed to meet those of the cylinder. This arch of cards is supported on two iron arches, fixed on each side of the cylinder. These iron arches or bridges have spikes on them, on which the several pieces, lags, or flats which compose the arch are fastened; exactly the same as described in *Plate III.* of the opening machine.

One of the iron arches is shewn at E E, in *fig. 2*, but is not drawn off its full breadth, because it would have concealed the surface of the cylinder from the sight; but in *fig. 1.* they are seen at C C, and in *fig. 3.* at f f. The card-teeth on the cylinder, and those beneath the arch, do not touch each other, but work as close together that a half crown can be put in the space between them without touching, and they are made very accurately circular, that they may always accurately preserve the same distance between.

B is a second cylinder of cards, the teeth meeting the first, as the figure shews. This cylinder revolves much slower than the first, its motion being taken from a small pinion, *t*, *fig. 1*, on the end of the axis of the great cylinder. This works a wheel, situated on a stud or pin *s*; which has also a pinion fixed to it, working a wheel *u*, fitted on another stud, and this carries a small pulley *v*, which communicates by an endless strap with a pulley, E, fixed on the end of the spindle of the small cylinder. As the whole of this train of wheel-work consists of small wheels turning large ones, it is plain the motion of the cylinder, B, must be very slow. On the opposite end of its axis is a bevelled wheel W, working another upon the end of an axis *b*, which has, at its opposite extremity, a pinion, turning a face or contrate wheel *i*, which is on the axis of the fluted feeding rollers between which the cotton passes, and is delivered to the cylinder. The cotton is, as was before described of the opening machine, spread out upon a feeding cloth D, which traverses constantly round two rollers *k* and *l*, one of which is turned by a pinion from the feeding rollers by means of an intermediate wheel at *k*. A small heavy roller, or cylindrical weight, is put upon the cloth beneath, as shewn at *f*, *fig. 2*, and, by its weight, always keeps the cloth to its proper tension, preserving a flat surface above, for the cotton to be spread out upon, and then advancing with the cloth, it is thrown in between the fluted feeding rollers, which deliver it gradually and equally to the cylinder, which carries it round, and works it against the cards fixed within the arch. In this process it becomes very equally distributed over the teeth in the cylinder, and gets carded in so doing. The cotton continues in this manner hanging sometimes in the teeth of the cylinder, and sometimes in those of the arch, but advancing slowly from one tooth to the next, till it has passed clear through the arch, and then it comes to the small cylinder B, which, as before-mentioned, is revolving slowly, in such a direction that its

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surface moves the same way as the cylinder, but much slower, and its teeth meet the teeth of the cylinder. Now, as before stated, it is the property of two cards meeting each other to distribute the cotton between them; therefore, the teeth of the cylinder B, having no cotton upon them, receive a full half of what is upon the teeth of the cylinder A, and as it constantly turns round, and bringing up fresh empty teeth, which in their turn take away the cotton from the great cylinder in a constant stream, and would soon empty it, but that it is supplied again with raw cotton from the feeding roller. The cotton taken up by the cylinder B, proceeds with it beneath, till it comes to the opposite side, and then it is removed by the *taker off*. This is a rod or iron bar *g*, situated parallel to the axis of the cylinder, and cut on the lower edge with fine teeth like a comb. It rises and falls parallel to itself, by being united to two rods, K, which are guided by sliding through small holes made in two standards shewn in *fig. 2*, and the lower ends of these rods are jointed to two cranks *e, e*, *fig. 3*, formed on a spindle, which is turned by a pulley *p*, with an endless strap from a pulley, S, fixed on the main axis, close behind the great pulley R. Now by the motion of these cranks, the rod *g* rises and falls, and at the same time moves a little to and from the surface of the cylinder B: indeed it describes a kind of ellipsis, and being so contrived by the direction of the motion of the cranks (caused by crossing the strap which works them), that it is descending at the time when its edge is nearest to the cylinder, and scrapes downwards against, or rather between the teeth thereof, and in consequence removes the cotton from them the whole length of the cylinder at once: and the motion of the crank is so quick, that by the time this piece of cotton, so detached from the teeth of the great cylinder, has moved round with the cylinder, B, as much as its own breadth, the crank makes another stroke, and, in consequence, the second piece detached from the teeth adheres to the first: the third adheres to the second, and so on. The cotton is thus *stripped* or *skinned* off the cylinder, B, in a continued and connected fleece. The disposal of this fleece constitutes the only difference between the breaking and finishing card. In the former it is received upon a plain cylinder, about half the size of the great cylinder A A, which is turned round with a proper velocity by an endless cord from a pulley on the axis of the cylinder B, a small roller resting lightly upon the top of this cylinder with its own weight, and by its pressure causes the fleece to lap regularly upon the cylinder, which continues to turn until it has made 15 or 20 revolutions. The fleece, being then broken off, forms a small fleece, consisting of 15 or 20 thicknesses, called the lap, which is carried to the finishing card, and treated exactly as the raw cotton was at first. The advantage of this method of treating the cotton has been explained, in a preceding part of this article, to consist in the great equality thus produced in the thickness of the lap, which being fed to the finishing card will produce an equable and regular sliver therefrom, and on this circumstance the perfection of the ultimate thread very intimately depends.

The *feeding card* is that which is represented in *Plate IV.*

The *feeding card*, as we have described, is gathered up into a thick fleece marked *m* in *fig. 1*, and *l* in *fig. 2*: it then passes between a pair of rollers *n, n*, which compress and flatten the fleece in its contracted state into a pretty firm and connected sliver or band, and deliver it into a can *n*. These rollers are situated

upon a spindle extending across the frame, and turned round by a pulley upon the end of it, which is connected by an endless band with the pulley E, upon the spindle of the cylinder B. By these means the cotton is reduced from the wool to a fine regular and even sliver, which is conveyed away in the tin can to the drawing frame, which we shall soon describe.

The carding engines in many mills are provided with small cylinders, known among the workmen by the technical term of *urchins*. These are covered with cards, and revolve, so that their teeth act with the teeth of the great cylinder, through proper openings left between the top lags of the arch. These small cylinders are turned round slowly by proper bands and pulleys from the main axis. These urchins are situated in pairs, one of which operates to take the cotton off the great cylinder, in the same manner as described of the cylinder B; but instead of being provided with a taker off, to strip the cotton from its surface, it runs close to the other urchin, of similar dimensions to itself, but turning with a different velocity, and the teeth meeting, so as to take it off the first urchin. This second urchin, having thus become charged with cotton, delivers it again to the great cylinder. The object of this contrivance is to obtain a more perfectly equal distribution of the cotton upon the surface of the cylinder, at the same time the urchins tend, by giving the cotton to the cylinder in a new direction, to work it more, as they prevent the cotton passing so quickly through the machine. The employment of urchins does not seem to afford any very great advantages, and it is not a very general system. When an urchin is applied to the lower part of the cylinder, immediately beneath the feeding roller, it is called a *timmer*: in this case it takes the cotton from the feed rolls, and gives it to the great cylinder as it revolves. The great cylinder of a carding engine, as well as any other part where the flue can escape, should be carefully inclosed by a tin plate, or thin boarding, to prevent its escape into the room, where it does great injury to the work people, producing an irritating and incessant cough, which is exceedingly hurtful, as well as the pernicious effects of such extraneous matter being received into the lungs. Carding engines have been used with two great cylinders, surrounded by a multitude of small urchins, in the same manner as those used for wool. (See *WOOLLEN Manufacture*.) These, having two cylinders, card the cotton sufficiently at one operation, without using a breaking card. The method is not near so perfect, because the equality and regularity of the sliver, produced by doubling the lap of the breaker 15 or 20 times, cannot be so completely attained by any other means, but leaves this equalization to be performed in the drawing frame. The double card, however, answers very well for coarse goods, and saves a great deal of attendance in conveying the lap of the breaking card to the feeding cloth of the finisher. Since the time that the drawing for *Plate IV.* was made, the cotton manufacturers have almost universally adopted what were at that time only partially employed, viz. cast iron frames for the carding machines, and iron circles for the cylinders, which are covered with lags of the best

will sometimes do in wooden frames, and thus destroy the card teeth very soon, as well as produce less perfect work. The same remark applies to all the other cotton machines, and, in point of expence, cast iron is far cheaper than wood

when a number of the same part are to be made, so that they can all be cast from the same pattern : in point of stability and duration no comparison can be made ; and when the mill is built fire proof, the safety from fire is not a trifling advantage, as it saves the manufacturer the heavy expence of insurance, or, what of course is nearly equal, the risk of losing his property by fire.

The drawing frame comes next to be described. *Plate V. fig. 1.* is an elevation of the machine, and *fig. 2.* is a plan of what is called a drawing frame of four heads, which is, in fact, a system composed of four distinct machines of exactly the same construction, but arranged on one frame, in the most convenient position to be used successively. *Fig. 3.* is a front view of one of the heads or separate machines drawn detached ; and *fig. 4.* is a section answering to it. In *fig. 1.* A represents a cluster, consisting of four of the cans brought from the carding machine : the four slivers from these are passed through the rollers of the machine, and united into one sliver, which is received in the can C, the machine having drawn it out, and extended it to four times the length of the others ; it is therefore the same size as any one of them. The construction of the rollers is explained by *fig. 3.* and also the figure at the left hand end of *fig. 2.* in which *a b* represents a live and dead pulley, upon the spindle of the principal, or front roller, by which it receives its motion from an endless strap. This roller is shewn, in *figs. 2.* and *3.* to be double, that is, it has two lengths or acting rollers upon it, each of which receives two distinct slivers from the cans *l, l, l, l, fig. 2.* In *fig. 4.* these two lengths of rollers appear like one, being behind each other, and exhibiting the circle marked *a*, the other circle described within this being the neck between the two lengths. This roller has another, marked *b*, placed directly over it, the pivots of which are retained in a vertical notch in the frame, and immediately above the pivots for the lower roller, as is shewn in *fig. 1* ; so that the whole weight of the upper roller rests upon the surface of the lower one, the bearings or notches in which its pivots are received being only to guide, not support it. Another pair of similar rollers, *c d*, are situated at a small distance from the former, and receive their motion by pinions *c, d, figs. 2* and *3*, which are fixed on the pivots of each respectively, and are connected by an intermediate wheel, *e*, fitted loosely on a stud, in the manner very plainly shewn in *fig. 1*, which also expresses the grooves or notches in the standards ; in these the pivots of the rollers are retained sideways upon one another, but, as before mentioned, the upper one rests upon the lower one. A small cross bar, *i, fig. 4.* extends from the pivot, or neck, of one of the upper rollers, *d*, to that of the other one, *b* ; and from the centre of this bar an iron rod, with a heavy weight, *f*, at the lower end of it, is suspended by a hook formed at the upper end ; so that this weight, as well as the weight of the upper rollers themselves, prels the upper rollers, *b, d*, upon the lower ones, *a, c*, and thus the sliver of cotton, *g*, which passes between them, is held very firmly down on the flutes in the surface of the lower roller, and cannot slip between them. The wheel *c, figs. 2* and *3*, which is fixed upon the pivot of the first roller, is much smaller in diameter than the wheel, *d*, upon the pivot of the back roller, to which it gives motion by the intermediate wheel *e* ; therefore it follows, that the motion of the front rollers, *a, b, fig. 4.* will be as much quicker than the back roller *c d*, in proportion as the wheel, *d*, is larger than the wheel, *c*, which gives it motion ; that is, the number of revolutions they will respectively make in any given space of time (as a minute for instance) will bear that proportion : but the back roller, *c*, (as shewn in *fig. 4.*) is much smaller than the other. The velocity of its circumference will, therefore, be slower than

a, in a still greater proportion than the proportion of the two wheels ; and the proportion is such, that the roller, *a b*, will, or ought to, draw four times the length of cotton through them which the back pair, *c d*, will permit to pass in the same time. The four slivers, therefore, being introduced from the cans *l, l, l, l, fig. 2.* between the back rollers *c, d, fig. 4.* and pressed with such force upon the flutes of the lower roller *c*, that they cannot slip through them, and the other pair of rollers, *a b*, holding the slivers in the same manner at another part, the consequence of their different velocities is, that as the front rollers, *a, b, fig. 4.* move so much quicker, they draw the sliver forwards faster than the back rollers will suffer it to come ; it must be drawn out, or extended in length, between the two pair of rollers, in proportion to their relative velocities, which, as before-mentioned, is the same as the proportion between the wheels *c, d, figs. 2* and *3*, communicating the motion from one to the other, multiplied by the proportion between the diameter of the two rollers, *a* and *c, fig. 4.* The four slivers, after passing through these in two distinct pairs, are all drawn together through a tin funnel *f, fig. 2.* by means of a pair of rollers, the upper one, *i*, of which merely presses upon the sliver lightly by its own weight, and delivers it into the can *k* : the lowest of this pair of rollers receives its motion from the pinion, *c*, on the end of the spindle of the main, or front rollers, by means of an intermediate wheel, *g*, fitted upon a stud or pin in the frame, and turning a pinion, *h*, fixed on the extremity of the spindle of the lower of the two rollers. These pair of rollers do not draw or extend the cotton, their velocities being accurately adapted to take up the four slivers as fast as they come through the others in two distinct pairs, and by drawing them through the funnel, *f*, to unite the four into one, and the slight pressure of the roller compresses them into a firm and connected sliver, which, though compounded of four, is only the same size as any one of the four put in, because it is drawn out to four times the length, and the effect of the machine has only been to straighten and lay the fibres parallel to each other ; for the motion the drawing produces among them, always tends to extend each individual fibre to its full length : and it is necessary to unite several slivers together, or the drawing would reduce the sliver to such a small size, that it would not bear sufficient extension without separating and breaking across. The plan, *fig. 2.* shews the disposition of four distinct heads, or sets of rollers, A, B, C, D, all fixed upon one iron frame, E, the upright of which is shewn in *fig. 1.* D is the first head, or that through which the slivers from the carding engine in the cans, *m, m, m, m,* are first drawn and united into one, which is delivered into the can *n*. In this head six cans, or ends, are shewn entering at once, in two sets of three each, and are all united into one, which will, therefore, if the rollers only draw four times, be rather thicker than those put in ; but the number of ends put in, as well as the draught of the rollers, is optional : and as the command of the cotton-spinner, who alters them for different kinds of cotton, or different kinds of yarn to be spun as he finds best, having the means of changing the pinions for others of different sizes. It is plain that the can, *n*, will be filled with the sliver in one-fourth or one-sixth of the time that the four or six cans, *mm*, will be exhausted ; and, therefore, it will furnish four cans, or ends, to the second head, *c*, which are placed at *o*, and drawn into one at *p*. Four of these, when filled, go to *q*, and are drawn into one by the head B, and delivered into *r*, which is taken to *s*, and by the head A, delivered finished into the can *k*, in which it is carried to the roving frame. The several heads, as the figure shews, are

reversed, with respect to each other, on the frame, to avoid the necessity of carrying the cans round to the opposite side of the frame in passing from one head to the next. Being thus reversed, that is, the slier of one moving in a contrary direction to that next it, it requires the straps, which turn the several live and dead pulleys, and which all come from one common axis, on which as many drums are fixed, to be alternately crossed, and put on in the common manner.

The drawing frame in *Plate V.* has now (1812) been drawn some years by a gentleman at Manchester, since which, the cotton manufacturers have very generally adopted a method of using three, and sometimes four pairs of rollers, instead of only two pair in each head: by this means, they draw the cotton at two or three times, and, by extending it only a small quantity at each, it is found to draw much more equably than by taking the whole draught at once. The construction of one of these heads will be readily understood, by examining a figure in the drawing (*Plate IX.*) of the spinning-frame we shall shortly describe, which drawing the writer of this article made from one of the spinning-frames in one of the most complete cotton-mills in the kingdom. The rollers used in this spinning and the drawing-frame are so nearly alike, that one may be very well understood from a description of the other.

The Roving-frame.—The preceding machines having prepared a slier, of which the fibres are laid parallel, it is necessary to reduce this slier to a convenient size for spinning into a small thread: but to make a sufficient extension to effect this reduction, it is necessary to give the slier a slight twist as it is drawn, that it may have sufficient cohesion to undergo the spinning.

The preparation of such rovings as shall be perfectly regular in size, and have an equal quantity of twist in every part, and which shall be exceedingly soft, is a most essential point in cotton-spinning. As it is impossible to correct these imperfections in the spinning, they will be given to the thread. A great number of different constructions of roving-frame have been in repute, at different periods, among cotton-spinners; but it is only lately that by a machine, called the double-speeder, it has been brought to perfection. The old roving-can frame, first introduced by sir R. Arkwright, is represented in *Plate VI.*, which was drawn when that machine was much more extensively used than it is now. The figure immediately beneath the title of this plate is a plan of the roving-can frame, and the figure below is a front elevation: in these, A is a horizontal beam supported by standards at each end, and carrying the several heads of rollers, and is therefore called the roller-beam. The machine contains four heads or frames of rollers, each of which receives four ends or slivers from the cans, D, D. See also the section in the corner. They enter two together between the back roller c, and are drawn out between them and the front rollers, b, d, to the proper degree of fineness, but which varies with the quality of the yarn which is to be spun. The slier, after passing through the rollers, is received into a tin can C, through a small funnel, N, at the mouth thereof. The can is supported on a pivot at bottom, and is kept in rapid motion by a band, working on a pulley fixed at the bottom of the can. The neck of the funnel, N, is guided by a collar, to keep the can steadily upright, as it revolves. The rollers of the machine are the same as those of the drawing-frame: they are turned by endless straps upon the pulleys, p, of the front rollers, coming up from similar pulleys on an horizontal spindle extended beneath the machine, through its whole length, and receiving motion by a live and dead pulley, E F, from the mill. The same spindle has pulleys upon it, which, by means of bands,

actuate the pulleys on the bottom of the can. These bands are of course conducted over pulleys, to change their directions, from the vertical pulleys on the spindle of E F to the horizontal pulleys on the bottom of the cans; but these are not shewn in the drawings. Each of the bands drives two cans, passing round the pulleys of both. The cans are made with a door, to open on one side, for taking out the cotton-roving, which falls into them from the rollers; and this door is kept closed by a ring, which fits upon the outside of the can, and keeps the door shut, when pushed down to the largest part of the cone; but when lifted up to the top, as shewn near N, the door can be opened, and the contained cotton taken out. L is what is called the clearer: it is a piece of wood placed over the top-rollers, and pressing gently upon them; its use is to prevent any part of the cotton *lapping*, that is, adhering to the roller, and being carried round with it, so as to wind it up, instead of drawing it through. The manner of action, in this machine, is easily gathered from the description: the slivers pass two together through the rollers, and are reduced or drawn out therein to the proper degree of fineness; then falling into the funnels, N, of the revolving cans, they are, by the rapid motion thereof, twisted round; because the centrifugal force disposes the cotton to lie round the inside of the can in a regular coil, forming as it were a lining of cotton to the whole of the interior surface; and by this means the end of the roving becomes in a measure attached to the can, and is twisted round by its motion, so as to form a coarse loose thread, with a very slight twist, and a very soft and open substance. The cans, when they have been in motion such a length of time as the attendant knows, by experience, they will be full of cotton, the ring is raised up, and the door opened to take out the roving, which is put into a box, and carried to a simple machine, called the winding-block: see the figure at the right hand corner of the plate. In this figure, which is an elevation, the box, containing two piles or coils of the roving, is plainly seen: just above it is a cylinder of considerable size, mounted upon a proper spindle, which is turned round by means of a winch: k, k, are two small bobbins, mounted on a wire, and receiving the end of the roving; they rest with their weight upon the surface of the great cylinder, and are by the motion thereof turned rapidly round, so as to wind up the roving very quickly on them. The rovings are conducted through holes in a strip or ruler of wood, which is moved slowly backwards and forwards, to lay the cotton equally on all parts of the length of the bobbin, and make a cylindric figure to the surface of the cotton wound upon it. It is the necessity for this winding of the cotton upon bobbins by a separate process, which is the greatest objection to the roving-can frame, because the tender roving is damaged by every operation it undergoes, viz. removing it from the cans, and winding it upon the bobbins, which must be done preparatory to the spinning. Another objection to the roving-can frame is the uncertainty in the manner of twisting; because, when the cotton applies itself to the interior surface of the can, by the centrifugal force, it occasions a stretching or draught on the roving, tending to lengthen it out before it is sufficiently twisted to make any resistance to the slightest draught. This would occasion no inconvenience, if the degree of draught or extension thus occasioned was constant, and uniformly the same; but this is not the case: for it constantly happens that the roving, by gradually gathering from the circumference toward the centre of the can, in the manner of a spiral, and when it arrives in the centre it coincides with the axis of the can, and of course, as no centrifugal force operates to draw it out in length, it merely twists it

round. In consequence of these irregularities in the action, which are constantly happening, the rovings thus produced are always full of thick and thin places; for when the cotton lies close at the inside of the can, it is considerably stretched by the centrifugal force, and becomes thinner and longer, and with less twist in any given length; but when it happens to fall in the centre of the can, it is of a larger size, and of a more rapid twist: but the quantity of these irregularities is very uncertain, because, even when the end of the roving, where it rests upon the coil of it, which is settled in the bottom of the can, is in the centre of the can, it is to be presumed that no draught will take place; but this is not certain, because the roving may swing out into a belly, and by its vibration will occasion some draught, though not so great as in the first instance. For these reasons, the roving-cans are not found to produce such perfect rovings as many other methods, and they are generally laid aside. Sir R. Arkwright saw these defects at first, and in his earliest machine devised a pair of rollers to be placed in the mouth of the funnel of the can, which were, by very ingenious mechanism, kept in constant motion, with such a velocity as to gather the cotton sliver regularly into the can, as fast as it was delivered by the drawing-rollers. By these means the sliver was held between these rollers, and, from their revolution with the can, received a determinate quantity of twist for every given portion of length. The difficulties of this were very great, to cause the rollers, in the mouth of the can, to take the sliver with the exact velocity required, as fast as the upper rollers delivered it; and even when this was accomplished, the objections we have pointed out would in some measure take place within the can; and after all the operation of winding the rovings upon the bobbins, preparatory for the spinning-frame, by the winding-block, is certain to do them injury, stretching and extending them improperly. The next improvement in roving was the use of *skeleton-cans*: these are light frames of iron, revolving on vertical pivots, in the manner of the cans themselves, in *Plate VI.* Within each of these skeletons or frames a common tin can is placed, and revolves with them, receiving the rovings as we have above described. These cans, when full, are removed to a machine called the stretching-frame, which gives them rather more twist, and extends them still farther in length, at the same time winding them on bobbins, which are called cops or coppins, being bobbins with only one end, the other end being a point, so that the cop in figure resembles a *fir-ball*, or pine-apple. The construction of the stretching-frame is the same, except in its proportions, as the mule: we must, therefore, defer the description of this method of roving till we have explained the mule, when we come to speak of the spinning process. Many mills, where cotton is spun on the most improved and economic system, have adopted a method of roving altogether upon the stretching-frame, producing rovings at once from the slivers of the drawing-frame; and this method is found to succeed very well, and be a great improvement upon the method of employing the roving-can frame. We shall next describe a roving machine, called by the workmen in cotton-mills,

The Double-speeder.—This is a roving-frame, which is extremely perfect in its operation, making better work than any other method: it is an improvement upon some machines made by Sir Richard Arkwright, at a very early period of the cotton manufacture; but the improvements are so essential and ingenious, that the maker or makers of them deserve the whole credit. Who is entitled to the invention of these improvements, we have not been informed; but we have seen machines, made by Samuel Smith of Ramsbottom, near Bury in Lancashire, which were extremely good. The drawings, en-

titled *Plate VII.*, or roving-frame, *Plate I.* also *Plate VIII.*, *Cotton Manufacture*, which we have given of this machine, have, like those preceding it, been made before the improvements were brought to the perfection they have since attained; and though the machine has the same parts, the proportions are such, that a machine, made exactly after them, would not operate so completely as those made by Mr. Smith, to whom we refer cotton manufacturers, who wish to adopt such machines, rather than attempting to make them from the drawings in our plates. They will serve, however, to illustrate the principles and mode of their construction. *Plate I.* is a horizontal plan of the machine; and *Plate VIII.* is an elevation, taken in front of the machine. In this figure, *A* represents the live and dead pulley, which communicates motion to the whole: it is fixed on a short axis, on the extreme end of which is a pulley, *B*, which communicates, by an endless strap, with another pulley, *D*, on an horizontal axis *g*: and this has at the end a bevelled wheel, which turns another on a vertical axis *k*, at the lower end of which a conical drum or barrel, *H*, is fixed; and beneath this it is formed cylindrical, to receive a strap, which passes round the pulleys, *b, b*, on the lower ends of the several spindles, *I, I, I*; and then returning to the drum again, the ends are united, and form an endless belt, which runs round the whole, turning them all at once with the same velocity: *l, l*, are small rollers, situated at intervals between every two pair of the spindles; these bend the strap out of the straight line, and thus cause it to press against the pulleys, *b, b*, of the spindles, and apply to a sufficient portion of their surface, to turn them round. This is very plainly shewn in *Plate I.*: each of the spindles, *I, I, I*, has at its upper end a forked piece of iron, *q q*, fixed on, which is called the flyer; and one of the forks is made tubular, to receive the roving as fast as it is twisted by the motion of the flyer, and convey it to the bobbin, which is fitted quite loosely on the spindle. The cans from the drawing-frame are, as shewn in *Plate I.*, set behind the machine; and the slivers are drawn through a double pair of drawing-rollers, turned by means of a train of wheel-work from the main spindle, bearing the live and dead pulley, *A*, *Plate VIII.* The slivers pass singly through the rollers, and are drawn out or extended singly; they then pass forwards, and two are drawn together through another double pair of drawing-rollers, the front pair of which are shewn at *c, c*, in *Plate VIII.*: *a, b*, are the pair of wheels which turn them from the main spindle; *f, f*, the weights; and *e*, the clearer. These rollers deliver the sliver to the flyers, at the top of the spindles, *I, I*, where it first passes through a collar, or eye-hole, *r*, formed on each of the flyers, exactly in the centre of the spindle, and thence it passes through the tube, *q*, before mentioned, to the bobbin *p*: the two back pair of rollers extend or draw out the sliver twice; then the two front pair, which are shewn in *Plate VIII.*, draw it again, and the spindles twist it once for every inch and a half. The tube of the flyer, running swiftly round the bobbin, lays the roving upon it as fast as the rollers deliver it out. The bobbins, *p, p*, are constructed so as to rise and fall upon the spindles, *I, I*, that they may lay the roving, coming from the end of the tube *q*, regularly upon the length of the bobbin. This is done by an horizontal bar, or rail of wood, *N*, which has holes through it, to admit the several spindles *I, I, I*, and the weight of the bobbin *p, p*, rests upon it; so that when it rises and falls parallel to itself, it takes the bobbins with it, elevating them as at *p*, in *fig. 2*. In this position, the bobbin receives the roving, and winds it on the lower part of them; but as the machine continues to wind, the rail with the bobbins gradually sink down; so that every turn of the roving falls close to, but not upon, the former turn, thus disposing it equally.

through all the length of the bobbins; and when they have descended to the lowest point, and the bobbins have been filled up to the top, it rises gradually up again. This ascending and descending motion of the rail and bobbins is thus produced: the vertical axis of the conical drum, H, has a bevelled wheel upon it beneath, (not seen in the figure,) which turns another, *s*, fixed on an horizontal spindle; at the other end of which is a pinion, *t*, turning a toothed wheel upon the end of an horizontal axis *v*, which carries a bevelled wheel *w*, turning another, on a vertical axis *y*, which has an endless screw at the upper end, turning a wheel, R, upon a long horizontal axis, which has two pulleys or wheels, M, on it: each of these receive a chain, which chains, at the lower end, support the rail N; and when the chains wind up, they elevate the rail with the bobbins; but when they let down the chains, the rail, N, descends. The reversion of the motion which is necessary to effect this, is done by the wheel, *w*, having another bevelled wheel, exactly similar to it, fixed on the same spindle *v*, and very near to the horizontal wheel worked by it: therefore this wheel, on the spindle *y*, being made to work either in one of these wheels or the other, will, in consequence, turn round one way or the other, elevating or depressing the rail N, and the bobbins accordingly: the lower pivot of the vertical axis, *y*, is supported in a horizontal lever, which is, by the motion of the rail N, when it arrives at the highest point of its movement, moved to bring the wheel to work in the opposite bevelled wheel, on the spindle *v*; and then it turns M in a contrary direction, bringing the rail, N, down again; and when it arrives at the lowest point, the bevelled wheel is again thrown in gear with the wheel *w*, and being thus turned in a contrary direction, it raises the bobbins up again. The connecting parts by which the bevelled wheel is shifted every time it is necessary to reverse the motion, are not shewn in the drawing, but they may easily be imagined: *x, x*, represent the weights which are suspended from the upper front rollers, the same as those used in the drawing frame.

What we have hitherto explained of this machine is the original roving-frame, tried by sir Richard Arkwright on finding the defects of the roving-can frame. The objections to this machine in its original state were, that the bobbins, when they became filled with roving, required so much more force to turn them round, in consequence of their superior weight, than when they were empty and unloaded; that they acted, to stretch or draw out the rovings, in the same manner as the can before mentioned; for the revolution of the flyer *g*, round the bobbin *p*, gives the twist to the roving at the nose or socket, *r*, of the spindle; and if the bobbin was stationary, it is evident the roving would be lapped round it once for every turn of the spindle: but this would require the roving to be delivered out by the drawing-rollers much faster than they are intended to do. The consequence of the bobbin being fixed would be, that the roving must be stretched out to a sufficient length to supply as much length as the motion of the end of the tube of the flyer, *g*, requires. Now suppose, instead of the bobbin being fixed stationary, it is only retained by the friction of resting its lower end upon the rail N, the roving will then only be stretched with as much force as will drag the bobbin round after the flyer, with as much velocity as the difference between the quantity of motion of the end of the flyer, and of the roving, as delivered out by the drawing-roller: this difference will enable the bobbin to take up all the roving as it is made.

Now it is plain, that to drag a heavy bobbin thus about, must require more strain on the roving than for a light bobbin, and in consequence, it is always drawn out smaller towards the time when the bobbin becomes filled. This is particu-

larly hurtful, because the roving, which will afterwards spin to the greatest advantage, is so extremely delicate as not to be able to bear the slightest strain; and if the machine requires it to undergo any strain, it must be twisted harder, and this will render it less fit to undergo the spinning. The manner in which these objections are obviated in the double speeder, is by introducing machinery which will give motion to the bobbin, and turn it round with such a velocity, that it will take up the roving just as fast as it is produced; but it is necessary, in effecting this, that the velocity shall be altered every time the bobbin has a new layer or roving beginning to be lapped upon it, because every time this happens the bobbin increases in its diameter, and must therefore move in such a manner as will cause its acting circumference to keep the same velocity at all times. To describe this see fig. 1, where for every bobbin, *p*, a small pulley is shewn resting upon the rail N, the spindle passing through its centre. The bobbin, which rests upon it, has a hole made in the under side of it, and the wheel having a pin entering this hole, so that the wheel, being turned round, compels the bobbin to turn with it. An endless strap, *n*, passes round all these wheels, having binders *o*, or pulleys, which bend the strap, and cause it to act upon a sufficient part of the circumference of the wheels, to take such hold as will carry them round. This endless strap also passes round a cylindrical barrel L, fixed upon the upper end of the conical barrel K, which is of the same dimensions as the barrel H, but inverted, that is, the large end of the barrel, H, is opposite the small end of the barrel K. This being the case, an endless strap, *m*, which is passed round both, will communicate the motion of one to the other, and if the axes of the two cones are parallel, the strap will preserve the same tension, whether it works at one or other end of the two cones, because whatever quantity the strap will be loosed by acting on a small part of one cone, it will at the same time be tightened, or taken up as much, by being upon the larger part of the opposite cone; but it is plain that this alteration of the acting point of the strap will produce a correspondent alteration in the velocity of the motion of the cone K, which is turned round by the strap. Thus, the motion of the cone, H, is equable and uniform in velocity, being actuated by wheel-work from the principal spindle of the machine. Now suppose the strap, *m*, at the top of the cone H, then it acts with a small diameter upon the large diameter of the top of the cone K, which therefore moves much slower than H. Now by shifting the strap lower down upon the cones, the acting diameter of H is increased, while K diminishes till they come to a point, where they will be of equal diameter, and of course have equal velocities; but beneath this point, the diameter of K will be the smallest, and of course its velocity will be greater than H, which actuates it. When the machine is first put to work, and the bobbins are all empty, they must move slowly, because they are required to follow the flyer round, so that they will only take up as much as the rollers produce; for if they were stationary, they would gather up, as before-mentioned, as much as the motion of the end of the flyer, therefore, within certain limits, the slower the bobbin moves, the more it will take up; and if it moved as quick as the end of the flyer, it would take up none at all. For this reason, at first starting the machine, when the bobbins are all empty, the strap, *m*, must be at such a height up the cones, that the bobbins will have their proper velocities to wind up the rovings as fast as they are required, and the bobbins rise or fall, as is requisite, to lap the roving equably upon them; but having thus covered each bobbin with one layer of roving, and beginning to wind another layer upon it, the acting diameter of the bobbin is

increased, and it must therefore turn so much quicker, (that is, it must make so many more turns in any given space of time,) as will cause the increased acting circumference to wind up no faster than it did when it was smaller. This seems, at first hearing, to be a paradox, that it should be requisite to turn round quicker to wind up no faster upon the increased radius; but it is to be considered that, by the bobbin being moved quicker, it follows and keeps nearer the end of the flyer tube, and therefore winds up less, because the quantity which the bobbin will take up depends on the difference between two motions, that is, the difference between the flyer and that of the bobbin which follows it. This increased velocity of the bobbin is occasioned by the strap, *m*, being, at the time when the bobbin is filled with roving up to the top, or down to the bottom, depressed or shifted down on the cones a small quantity, which occasions, as before-described, a small increase in the velocity of the motion of the cone *K*, and of the bobbins. The depression of the strap is performed by a lever, which takes hold of the strap with a fork, and when urged, leads it up or down upon the conical barrel. This lever is actuated by a snail, upon the axis of which is fixed a ratchet-wheel, turned round by proper clicks, levers, and other connecting mechanism, one tooth every time the bobbins and rail, *N*, begin to ascend and descend, or, in other words, arrive at the extreme limits of their motion. Then the snail acting on the lever depresses the strap a sufficient quantity, to produce the alteration of velocity required.

Thus, as the bobbins increase in diameter by the addition of successive layers of the roving, they adapt their velocities to that increase, and taking it up just as fast as it is produced, and no faster, so that the roving, as it passes from the end of the flyer tube to the bobbin, is never stretched, and never becomes slack. The intelligent mechanic will readily perceive that this is practicable, but at the same time he will be sensible of the accuracy requisite in the adjustment of such a machine to its work, and the difficulty of making this adjustment for different sizes of roving. This, perhaps, is the only bar to its general use, that it requires a skilful mechanic to attend and take charge of it, because every different size of roving, which is made in it, will require a different rate of increase or decrease of motion, by means of the strap *m*, for a large thread causes the diameter of the bobbin to increase more rapidly than a small one, and therefore the quantity of shift which the strap, *m*, makes every time on the two cones *K*, *H*, must be determined by the size of the roving, as is also the height at which the strap shall stand when the machine is first let to work, and the bobbins are all empty. These adjustments are made in the lever snail, and other connecting mechanism, which are omitted in our plates. We have attended for a long time to the action of several double speeders of this kind, made by Mr. Smith, and adjusted by him, which performed their work in the most perfect manner, making a roving so loose and soft, that it would part with the slightest force, but at the same time as regular and even as possible, and the yarn spun from it was greatly superior to any which could be produced from the same material by any other means we have seen. We venture to prognosticate that the general introduction of this machine, when a sufficient number of managers are instructed how to make it work properly, will be a great improvement of a most essential department in cotton-spinning.

The rovings, thus prepared on bobbins, are carried to be spun, either, as before explained, in the water-frame, or mule. We shall describe the former first: it is constructed in two very different forms; and though in both the operating parts are the same, the machinery which actuates them are very different. One is called the water frame, being the original

spinning frame, as first constructed by Mr. Richard Arkwright, whilst the other is a more modern construction, and is known by the name of the throstle frame. Their comparative advantages we shall speak of after having described them both by the aid of drawings made from the most improved machines of both kinds. See Plate IX. which contains a drawing of

A Water spinning frame, taken by the writer of this article from Messrs. Strutt's mill, Belper, Derbyshire, whose works are the most complete for the water-spinning trade of any in the country. *Fig. 1.* is an elevation in front of the whole frame; *fig. 2.* an elevation endways, and *fig. 3.* is a plan: the remaining figures are the parts on an enlarged scale. In all the three first figures, the same parts are designated by the same letters of reference: *A* is a bevelled wheel, fixed upon the horizontal axis, which extends through the whole length of the mill. This turns a smaller bevelled wheel upon a vertical axis *B*, which has a drum, *C*, at the lower end, and by a strap, *a*, actuates the whole machine. Another strap, *b*, goes the other way, and works another frame on the opposite side, the drum, *C*, being common to both. The spindle, *B*, passes through the drum, *C*, with a circular fitting, so that it slips freely round within it, without giving motion to the drum, except when it is cast into gear. This is done by two locking bolts, shewn by dotted lines passing through the drum, and both fixed into a collar or socket-piece *d*, fitted to slide up and down the spindle. It has a groove formed round it, in which a fork, at the end of a lever *e*, is received, so that the fork embraces the piece, *d*, in the groove, and when lifted up, raises the two locking bolts with it. This lever is raised by the power of a second lever *D E*, the extremity, *E*, of which, being depressed, raises up the lever *e*, and unlocks the drum from the spindle *B*, by withdrawing the locking bolts from their contact with an arm, *f*, of a wheel, *g*, which is fixed fast on the spindle beneath the drum, and therefore turns with it; but the locking bolts being let down, that their ends may project through the drum, and intercept the cross arm, *f*, of the wheel, the drum and all the machinery are put in motion.

The endless strap, *a a*, passes, as shewn in the figure, the whole length of the frame, makes a turn round the pulley *m*, and comes back again. Other pulleys, 1, 2, 3, of the same dimensions as *b*, are situated, at intervals, in a direct line between the drum *c*, and the pulley, *m*, to bear the strap, and in the intermediate spaces between these pulleys, the vertical spindles marked *n* are placed in pairs, exactly opposite each other. On the lower end of these, small wheels, *x*, called binders, are fixed, and the strap, *a a*, pressing against them, as shewn by the figure, turns them round, the object of the pulleys 1, 2, and 3 being to bend the strap out of the straight line sufficiently, to make it apply to the surfaces of the several binders and turn them round. The last pulley, *m*, is fitted in a frame, and can, by a screw 4, be moved to strain the strap tight. Above each binder, and on the same spindle, a wheel, *b*, is fixed: it receives two belts *i, k*, (*fig. 3.*) which turn four of the spindles *l, l, l, l*, each belt giving motion to two spindles. The binders *x*, (see *fig. 5.*) are fitted to slip round on their spindles *n*, but can, at any time, be united thereto, to give them motion by a locking bayonet *q*, which is cast in or out of action, at pleasure, by a small lever 10, in exactly the same manner as the locking of the principal drum: therefore, by the lever 10, any four spindles can be detached from the machine at pleasure. The spindles, *n*, of the binders have each at the upper end a pinion, which turns a face or contrate wheel *p*, fixed upon the spindle of the front rollers which give out the cotton to the spindles. These rollers are arranged in distinct heads or frames, containing four lengths in each, which supply four spindles.

The construction of one of the heads is shewn in *figs.* 4, 5, and 6; *fig.* 4. being a section of the rollers and spindle; *fig.* 5. a front view of the rollers; and *fig.* 6. an end view. In these, *p* still denotes the face wheel, and 4 the lower front roller. Upon this, which is fluted in the acting parts, the upper rollers 5, made in two separate lengths, rest, and are pressed down upon the lower one by two heavy weights, 6, 6, which are suspended, by means of hooks, 7, from the necks or small parts of the upper rollers, and thus keep them firmly down upon the flutes of the front roller 4. On the opposite end of the front roller to the wheel *p*, a pinion, *r*, of eleven teeth is fixed: this turns a wheel, *s*, of 28 teeth, which is mounted on a stud or pin, and has a pinion, *t*, of 16 teeth fixed to it, which works a wheel, *w*, of 32 teeth, fixed on the end of the middle roller, shewn in the section, (*fig.* 4.) at 12, whose motion will be to the front roller nearly as five to one. On the other end of the roller is a pinion of 10, which turns another of 15, on the back roller, 13, by means of an intermediate wheel, so that this turns only once for one and a half turns of the middle roller; consequently, the roving 14, (*fig.* 4.) which is introduced between the back rollers, from the bobbins or cops set up in a frame *F*, (*figs.* 1 and 2.) above the machine, is, in passing between the back and middle rollers 12 and 13, drawn out one and a half times; then between the middle and back rollers 12 and 14, it is extended five times more, making a draught or extension of $7\frac{1}{2}$ times in the whole; and as fast as the rovings come through the front rollers, they are twisted into a thread by the rapid circular motion of the spindles. But these we have to explain; they are straight steel arbors, *l, l*, (*fig.* 4.) on the lower end of which the whirls or pullies, which receive the band, *i*, for them, are fixed: these spindles are mounted in a frame common to them all, which consists of two rails 14, 14; the lower one supporting the points or toes of the spindles, and the other having bearings for the cylindrical parts of each spindle, and a strip of wood is screwed against this to keep them up to their bearings. Above this bearing the spindle is only a straight cylindrical wire, and on the upper end of it the flyer, 15, is fastened, either by screwing it on, or it is stuck fast on by friction, which is sufficient to carry it about. The two arms or branches of the flyer are sufficiently distant for them to revolve round clear about the bobbin 16, which is fitted loosely upon the cylindrical spindle, and with liberty to slide freely up and down upon it. The weight of the bobbin is supported by resting on a piece of wood 17, attached by screwing to a rail *M*, which has a slow rising and falling motion, equal in extent to the length of the bobbin between its shoulders, by which means the thread, as it comes through the eye formed at the ends of either of the branches 15, of the flyer, and is wound by the motion thereof upon the bobbin, becomes equally distributed throughout, its length giving it a cylindrical figure, instead of heaping all the thread at one part, like a barrel, as would happen if the bobbin did not rise and fall. This motion of the bobbin is produced by a bent lever, 16, (*figs.* 1. and 2.) suspending the rail *M*, with all the bobbins upon it, from the arm 16; the lower end of the other arm, 17, bears against, and is moved by a heart or eccentric wheel 18, nearly of the figure of a heart, which is fixed on an horizontal axis extending the whole length of the machine, and at the other end it bears a similar heart 18, (*fig.* 1) fixed on it, which operating upon another lever 16, suspending the other end of the rail *M*, thus causing it, when the hearts are turned round, to rise and fall equally at each end, or parallel, and move all the bobbins resting upon it together. The motion is given to the spindle of the heart

18, by a small contrate wheel on the end of it, which is turned by a pinion on the lower end of the vertical spindle 19, receiving its motion by a pair of bevelled wheels from an horizontal spindle 20, in the middle of which is a cog-wheel 21, turned by a spiral piece of iron 22, which is fixed on the main spindle *B*, just beneath the great bevelled wheel. It operates in the same manner as an endless screw, turning the wheel, 21, round one tooth for every revolution of the main spindle, and this slow motion is communicated by the spindle 19, and wheel-work just described, to the hearts, which revolve with such a velocity, as will cause the bobbins to ascend and descend so fast, that they lie every turn of the thread close by the side of that preceding it, but not upon it, so that the figure of the bobbin, when filled with thread, will be nearly cylindrical.

The bobbins of the roving frame are put upon a wire, or temporary spindle, and in this state are set up in the frame, *F*, in two rows, one above another, so that they will all turn freely round when the rovings are drawn off from them. These rovings are conducted over wires, as shewn in *fig.* 2, to lead them in the right direction, and are brought, two together, through wire staples fixed in the board *G* (*fig.* 4.), then through notches made in the edge of a piece of iron plate fixed on the edge of the board, and projecting up above the surface of it, and after passing through these notches the rovings enter the back roller 13, in *fig.* 4. The board, *G*, has a short traversing motion backwards and forwards, by which means it causes the roving to travel backwards and forwards between the rollers, or it would soon, if constantly conducted through the same part of the rollers, wear out the flutes at that part, making a smooth ring round it: but by this traversing motion the wear is equally distributed over the whole length of the fluted rollers, and does not act partially at any one part. The motion is caused, as shewn in *fig.* 4, where 18 is the spindle of the hearts 18 (*fig.* 2.), situated immediately beneath the board *G*: it has a cog-wheel of 18 teeth fixed upon it, turning another, *H*, of 36 teeth, on the axis of which a small crank, *K*, is formed, and by means of a connecting rod draws the board, *G*, backwards and forwards every time it makes a revolution, by means of the cog-wheels, which will be once for every two turns of the hearts. The rovings, two together, as before stated, enter between the back rollers, and then pass forwards to the middle pair, receiving in the passage a draught or extension of one and a half; then advancing through the middle rollers to the front, they are, by the motion thereof, drawn out five times, and in this state delivered to the spindle *L*, which twists the fibres round each other the instant their ends come out, before the rollers leave the other ends, or they would fall to pieces, being drawn out so fine, that the cohesion of the fibres is insufficient to bear any thing, and the twine given to the roving is entirely lost, for it was at first only one turn in $1\frac{1}{2}$ inch in length; and this $1\frac{1}{2}$ inch, being by the draught of the roller drawn out to more than 13 inches, the twist of one turn in this length is imperceptible, and adds no strength whatever to the roving, so that it is necessary the spindle should, by the connection of the thread 41, passing down from the rollers to its flyer, give a twist to the fibres the instant they come through the roller, so that by twisting one end of each fibre round the other, whilst the opposite ends are held fast between the rollers, they will become a thread sufficiently cohesive to advance towards the spindle, and receive its full quantum of twist to become a hard and strong thread: it passes through a wire eye or staple fixed in a board at 34, which changes its

direction into a line with the spindle, to which it is connected by passing through the eye formed at the end of either of the branches of the flyer, which revolves with the greatest rapidity along with the spindle, and thus give twist to the thread. The bobbin does not partake of the motion of the spindle, but is retained by the friction of its lower end resting on the piece of wood 17, and this is increased by a washer of leather put under it: then, as before explained of the hobbin of the roving frame, the thread, by the motion of the flyer, drags the bobbin about after it with a velocity equal to the difference between the motion of the end of the flyer, and the motion of the thread as delivered out by the front rollers. When the frame has been so long at work, that the bobbins become filled with thread, the child in attendance, by the handle of the lever 10 (*fig. 5.*), disengages the binder *x*, of the four spindles from its axis *n*, and then they, as well as the head of the rollers belonging to them, stop, and the child breaks the thread; then pulling off or unscrewing the flyer, he lifts off the bobbin, puts on an empty one, on which the end of the thread is previously lapped to make a beginning: the flyer is next fixed on, the thread passed through the eye at the end of the flyer, and it is ready to work again: the eye of the flyer is made open at one part, being curled in the manner of a cork-screw just at the end, so that the thread can be hooked in and out of it by the child, but is in no danger of getting out by the motion of the flyer in its work. When a thread accidentally breaks, it is not always necessary to stop the spindle to unite it, but the attendant takes hold of the broken end which belongs to the bobbin, and draws off a considerable length, a yard for instance, from the bobbin, and breaking it, throws this away, because it has every chance of being unfound: then taking the end in the finger and thumb, and applying it against the end of the roving which is coming through between the rollers, leaving them overlapping a small quantity, and letting them go from the finger and thumb, the ends are instantly twined together, and united into one sound thread. But this requires some dexterity, for if the end of the thread is held so long between the fingers in applying them together, that the roving coming through the rollers advances the length of the fibres of the cotton before it is let go, and suffers the spindle to twist it, the fibres will part and the thread breaks afunder, or is never formed at that part; it is therefore necessary to catch the roving as close as possible to the rollers, and apply the end of the thread quickly to it, then letting them go instantly, the fibres are twined in with each other, and the union takes place so perfectly, that it cannot be afterwards discovered where the joint was made. The lower rollers are made of cast iron, turned extremely true, and fluted by an engine; the upper rollers are also cast iron, but are covered with leather in the acting parts, so that this soft substance holds the cotton more firmly upon the flutes of the lower one than any other method would, as the roving is not liable to lap round the rollers like the sliver of the drawing frame. No clearer is used; but instead thereof, a small wooden roller covered with leather is placed over, between the front and middle roller, but it merely lays upon them, having no pivots or support; its surface is rubbed over with chalk or whiting, and this it communicates to the leather of the upper roller, and is found to improve their action, probably by not suffering the cotton to slip beneath the rollers: *fig. 4.* shews, that the middle and back rollers have their weights to keep down the upper rollers upon them in the same manner as the front rollers; but the weights are very different, the front weight, 6, being 20lbs., whilst the middle weights are but a few ounces, and the back rolls have a weight of

2lbs. The reason for the front roller requiring so great a weight is, that it is necessary for them to press and hold every one of the fibres of the roving while passing through them extremely tight; because if it only held a few in the middle of the roving, the others towards the edges of the roving might, by the twisting, be drawn out before their ends were fairly twined into the thread, and this would render the thread fuzzy in its whole length: the instant the foremost end of a fibre comes through between the rollers, it should, by the twine of the spindle, be twined over the middle of some other fibres which are coming through, and over the ends of others which have altogether escaped the roller, and the smoothness of the surface of the thread altogether depends upon this being done instantaneously on the foremost end presenting itself through the rollers; for the effect of all the preceding operations has been to disperse the ends of the fibres equally, so that they effectually break joints with each other, and then being equally twined, it forms a thread of equal strength in all parts.

The numbers of the wheel-work for the rollers of the roving frame, are varied with every different number of cottons which is to be spun; the draught being altered, when requisite, to produce such an extension of the sliver in passing through the rollers, as will make the roving, when finished, 4.3 times the weight (length for length) of the yarn it is to be spun into. This is a pretty general rule in cotton-mills, and the roving is occasionally measured and weighed, to ascertain if the machines are drawing the proper quantity, and if not, the pinions are changed for others which will produce the proper degree of extension. It is in this stage that the size of the yarn is determined, and the spinning frames have, in general, the same draught; but the velocity of the spindles with respect to the roller, so that they will give a greater or less degree of twine to any given length, is varied in spinning different kinds of twist, whether hard or soft twist. The alteration is made by employing larger or smaller pulleys, or whirls, on the spindles which cause them to revolve with a slower or quicker motion. Neither do the rollers of the spinning-frame give out the same quantity of roving in a given time when spinning coarse or fine goods, or when spinning very high numbers, as No. 60: the front rollers are adapted by the wheel-work to revolve at the rate of 35 times *per* minute; but for coarser goods, some of them will turn 60 times *per* minute: this is because a fine thread requires more twist in a certain length than coarse.

The frame from which the drawing was taken contained ten heads, or forty spindles, on each side, the frame = 80, and the same on the opposite side of the drum, to be driven by the strap *b*, making 160 spindles, actuated by one cog-wheel *A*.

The construction of the locking bayonet *d*, for connecting the drum with the main spindle, we have explained; but one circumstance was then unnoticed, *viz.* that the bar *f*, *fig. 1.* is not permanently fixed to the wheel *g*, but that the wheel has a groove turned in the edge of it like a pulley; and an iron hoop or clip, made in two halves, screwed together, is fitted round the wheel in this groove, and to this clip the cross-bar, *f*, is united, by the ends of it turning down, and being received between the ends of the clip, the same screw-bolts holding all together. The consequence of this construction is, that the machine is not suddenly jerked into motion when the bayonet is let down, and intercepts the arm *f*, which is revolving rapidly with the spindle and wheel *g*: instead of jerking the frame, the bar, *f*, for a moment becomes stationary against the point of the

bayonet, the wheel, *g*, slipping round within the clip, but the great friction of this soon sets the machine quietly in motion; and when it arrives at its full speed, the friction of the clip is sufficient to keep it in motion, without slipping any more, unless an accident happens, and then it is very useful, as it prevents the machine being broken.

The *throstle spinning-frame* is delineated in *Plate X.* of which *fig. 1.* is a section taken across the length of the frame; *fig. 2.* is an end view, and *fig. 3.* is an elevation of the machine in front. After the minute description we have given of the construction and operation of the roving-frame and water-frame, it will not be necessary to be very diffuse in our account of this machine, which has the same parts as those machines, but only differs in dimensions and proportion. The same letters of reference are employed in all the figures, and *A A* represents the live and dead pulley actuating the whole, fixed on the end of the spindle of a long tin cylinder *B*, which is called the throstle, and turns all the spindles and other machinery at once. On the main spindle of the throstle a pinion, *a*, is fixed: this turns a wheel *c*, which has a pinion, *b*, fixed on it, turning the wheels *D* and *E* (*fig. 2.*) by the intermediate wheels, *d*, on one side, and *e* and *f* on the other. The wheels, *D* and *E*, are fixed on the ends of the spindles of the front rollers *X*, as is plainly shewn in *fig. 3.* These rollers are made in lengths, which serve six spindles, and the lengths are united by connecting boxes, as shewn at *F*, to other lengths, so that one train of wheel-work, *a C b d e f E* and *D*, will turn the front rollers for 112 spindles, or 66 on each side of the frame, and then the rollers are made in 11 lengths. Some frames are longer, others shorter than this. Our drawing only contains 12 spindles, and two of these at each end are removed, to shew the works inside of the frame: at *g* a pinion is fixed on the spindle of the front roller, and turns a wheel on the end of the middle roller, by an intermediate wheel and pinion on a stud; and at the opposite end of the middle roller is a wheel *h*, turning the back roller with its proper velocity by means of an intermediate wheel, so that the motion of the rollers in this frame is exactly the same as in the water-frame. The spindles, *l, l*, are all driven by bands from the throstle cylinder *B*, the manner in which they cross being shewn at *k*, *fig. 1.* The bands are very loose, and, as the figure shews, are inclined, so that their weight tends to draw them tight, and turn the spindles, *l, l*, about with the proper velocity; but till the child attending the machine can, by pressing his knee against the wheel, as the pulley is called, stop the motion of any one spindle for a moment whilst a broken thread is repaired, the band slipping round it all the time. The spindles, being exactly the same as the water-frame, need little explanation, more than to enumerate their parts, which are, the bobbin *m*, the flyer *n*, stuck by friction, or else screwed on the top of the spindle, and its branches ending in a curled hook, through which the thread is passed to the bobbin. This is fitted quite loose on the spindle, and rests its weight on a piece of wood *o*, fixed to the underside of a rail *N*, which rises and falls, to lay the thread regularly in a coil upon the bobbin, as fast as it is taken up thereby. The rise and fall are thus produced: the two rails, *N, N*, on opposite sides of the frame, are suspended by iron rods, *p, p*, from horizontal levers *G*, which are mounted on an axis, extending the whole length of the frame, and having as many of the levers, *G*, upon it, as are necessary to suspend the rail, *N*, without bending. *H* is an iron rod jointed to the lever *G*, and coming down to a short lever *I*, which, at the opposite end, to its connection with *H*, rests on the surface of the

heart *R*, fixed on a spindle, which is turned by the following train of wheel-work. The spindle of the wheel and pinion, *C b*, passes through the frame, and by a pair of bevelled wheels, *L* (*fig. 3.*), turns a vertical axis *M*, on the lower end of which is an endless screw, giving a slow rotation to the spindle of the hearts by a tooth-wheel, *m*, thereon, which is turned round one tooth by every revolution of the endless screw. A heavy weight, *P* (*fig. 1.*), is suspended from the lever, *G*, to counterbalance, and cause the end of the lever, *I*, always to press upon the surface of the heart *R*, which, as it turns round, elevates and depresses the bobbins on the opposite sides of the frame alternately. The joints of the levers, *G* and *I*, with the rods, *H* and *p p*, are made, as the figure shews, adjustable; that is, the centre pins are fixed to the levers by fitting in grooves, and are held in by nuts, so that they can be fixed at different distances from the centre, to accommodate the acting radius of the levers, so that the motion given by the heart, *R*, may be made to correspond with the length of the bobbin between the shoulders.

The bobbins for the roving are set up in a frame at *S S T*, between the two sets of rollers, *X, X*, and the roving is conducted immediately between the back rollers: but, as it goes through the same process as before described in the water-frame, it is needless to repeat it. The traverse motion, to prevent the cotton wearing away the rollers in any one part, is sometimes omitted; but we have seen throstle frames in which the whole of the frame *S T*, consisting of one board, *S*, below, and another, *T*, above, connected by proper pillars, together with all the bobbins of rovings, had a small traverse motion, which is found to be a great advantage in the wear of the rollers.

Respecting the comparative advantages of the throstle-frame and the water-frame, cotton-spinners are divided in their opinions: the simplicity, and consequently low price in the first erection of the throstle, is its recommendation, and it is generally stated to be driven with far less power, because it has fewer parts. To set against these advantages, it is said, that when the bobbins are filled, and require to be changed, the whole frame of 112 spindles must be stopped at once, by shifting the strap to the dead pulley *A*; whereas in the water-frame, any four spindles can be stopped together, by casting off their binder; and it is only necessary to stop the whole frame by the casting off the great drum, when the frame is to be repaired, or is out of use for a day, or longer period.

We have now explained the manner of spinning cotton into a thread by the water-frame, and shall proceed to describe the construction of the other method of spinning, viz.

The Mule.—This machine was introduced by a Mr. Crumpton, who lately received a reward of 5000*l.* from parliament for the invention, which, as before mentioned, consisted only in the combination of Hargreave's spinning jenny with sir Richard Arkwright's drawing rollers. *Plate XI.* contains drawings of one of the best constructions of this machine, in which *fig. 2.* is an end view of the whole machine, and *fig. 1.* an end view of the carriage alone. *Fig. 3.* is a front view, and *fig. 4.* is a view of the operative parts detached: *fig. 5.* a similar view in another stage of its operation. As this machine is extremely complicated in its movements, it will first be proper to explain these movements before entering upon the machinery which causes them. This is shewn in *figs. 4* and *5*, where *W* represents a bobbin of the roving frame set up in a proper frame, and the roving is conducted from it, through three pairs of rollers, *A, B*, and *C*, which have the same draught as the

rollers for the spinning-frame, and are moved by similar wheel-work : but the upper rollers, *a*, *b*, *c*, are weighed down in a different manner : thus, *d* is a piece of metal resting on the neck of the front roller, *a*, at one end, and the other end upon the middle of a second piece *e*, which bears upon the necks of the other two pairs of rollers, *b* and *c* ; then an iron rod *f*, coming down from the piece *d*, loads all the three upper rollers *a*, *b*, *c*, at once, by means of a lever *g*, which is hooked beneath a fixed rail of the framing supporting the rollers at one end, and the other is made with a heavy knob, so that the purchase, or leverage of this piece *g*, draws down the wire, *f*, with sufficient force to load all three rollers with their relative forces : thus it is plain the roller, *a*, must bear the principal weight of the lever *g*, because the wire, *f*, is nearer to the roller *a* ; but as it acts upon the piece, *e*, with a considerable length of leverage it bears lightly upon it, and this again bears upon two, and therefore still less upon either, the weight of the end of *d* being divided upon two rollers *b*, *c* ; but it bears most powerfully upon *e*, the point or end of *d* being nearest to that roller, so that the operation of all these pieces is to load the three rollers nearly in the same proportion as the rollers of the spinning frame : but this proportion can readily be altered by shifting the acting lengths of the levers.

The roving, after passing through the rollers, is taken up by the spindle D G : this is placed rather inclined, but without any bobbin or flyer, like the spindle of the water frame ; it is merely a plain conical arbor, supported at its point, or toe, in a step made on the rail, E, of the frame, and in a bearing at F, against another rail. It has nothing to keep it up against this bearing, the draught of the band, which passes round the pulley *b*, and gives motion to the spindle, being sufficient for this. The end of the thread is merely lapped round the upper end of the spindle, and its accumulation upon itself soon forms a mass G, which is called a cop, or coppin. Now it is evident that, from the inclined position of the spindle, it will, when turned round, give twist to that part of the thread which is between the end of the spindle and the roller A, although the spindle and the direction of the thread do not coincide, because, when the spindle is turned, the thread will slip over the top end of it and receive a twist, without winding up upon the cop ; but when it is required to wind up, the thread, or wire H, is pressed down upon the thread. This removes it from the end of the spindle to the middle of the cop, as shewn in *fig. 5*, and then the motion winds up the thread upon the cop instead of twisting it. The wire, H, is extended at the end of a lever H I, moveable on a centre I, in the manner shewn in *fig. 5*, but when left at liberty, the weight of the opposite end of the lever restores it to the position *fig. 4*, and then the spindle twists the thread instead of winding it up.

The operation of the machine is this : the rails E and F, supporting the spindle, are part of a carriage or frame carrying above 100 such spindles, and moving on wheels which traverse on railways to and from the rollers in a direct line, for the extent of a yard and a half. Now suppose it wheeled home, that the ends of the spindle are close to the front roller A, then suppose the rollers set in motion, they take in the roving from the bobbin W, and draw it out or extend it eight or more times, giving it out between the front roller A, to the spindle G, which, with its carriage, recedes, by the movement of the machine, from the rollers, taking up the thread as fast as it comes out between them ; and, at the same time the machinery draws the spindle back, it turns it round rapidly, giving twist to the

thread as fast as the rollers deliver it out, and thus producing such a compression of the fibres by twisting them round each other, as will form a thread of sufficient strength to bear *stretching*. This means, that when a yard of thread has been given out by the rollers their motion ceases, so that they deliver no more, but the spindle continues to recede from the rollers to the further distance of a yard and a half, twisting the thread all the time it stretches it out in length, till it forms a fair and strong thread. The twisting motion of the spindle then stops, as does also the drawing-out movement of the spindle, with its carriage. Thus one yard and a half of thread is made and finished. The attendant to the machine now thrusts the spindle, with its carriage, home to the rollers, holding the wire H, done in the manner shewn in *fig. 5*, and at the same time turning round the spindle at such a rate, that it will wind up the thread upon the coppin, and the wire H, which is held down by the hand, is so humoured, as to make the thread wind up with regularity. The rotatory motion given to the spindle is, in this instance, done by the other hand of the attendant, and is so accommodated, as to wind up the thread just as fast as the advance of the spindle towards the rollers requires, and no more ; but when it arrives close to them, the wire, H, is raised up, and the machinery is put in motion again, the rollers begin to draw out, and the spindles to recede, turning all the time. The mechanism by which all this is effected is described by *figs. 1*, *2*, and *3* ; first, see *fig. 2*, where K is a live and dead pulley for the endless strap actuating the whole by the power of the mill. The pulley is mounted on a short spindle, having a winch or handle, L, at one end, and on the other a large pulley M, which has a number of different-sized grooves formed round it, to receive an endless rope *i* ; see also *fig. 2* : this rope, after making a half turn round M, passes under a wheel *k*, fixed on a pin or stud projecting from the frame. From this wheel the rope, *i*, proceeds to another wheel, *l*, at the opposite end of the frame, and returning from this goes over a wheel situated close behind *k* on the same centre pin. The ends of the rope are then joined, and it forms an endless band, which, when the strap is cast on the live pulley *k*, and the wheel, M, turned by it, the rope, *i*, constantly runs in a straight line from the wheel *k* to *l* ; but in this passage the rope makes a quarter turn round a wheel *m*, upon a vertical axis, which is mounted on the frame or carriage E F, for the spindles D, G, shewn separately in *fig. 1*. The rope, *i*, not only passes round the wheel on this spindle, but goes forwards into the carriage, and passes round a groove upon the upper end of a vertical drum, (not seen in the figures,) which has several bands upon it, each driving two spindles, D, by passing round the pulleys, *b*, of two of them, as shewn in *fig. 3*, in which it is also seen that the bands are all at different heights, that they may not interfere with each other upon the drum, but each take its proper place upon the length thereof. The carriage runs upon four wheels 1, 2, (*fig. 2*.) two of which are placed at each end, and run upon an iron railway, so that the carriage containing all the spindles and drums runs backwards and forwards, to and from the rollers, for the length of a yard and a half. But during this motion, the power of the mill is all the time conveyed to turn the spindles by means of the endless cord *i*, which, as before-mentioned, making a straight line from the wheel *k* to *l*, will not be affected by the motion of the carriage, but will always circulate round the several wheels, and give motion to the drum which turns the spindles : 4, (*figs. 1* and *2*.) is an iron bracket, supporting the axis I I of the lever, H, *fig. 4*, which supports the wire H, and as many of these levers are fixed on the axis I, as shewn in *fig. 3*, as are suffi-

cient to make the wire H, stiff enough to press down all the threads together, in the manner of *fig. 5*. The remaining parts of the carriage, being only its frame, are evident from *fig. 1*, and need no farther notice, except a double pulley; that is, a pulley 5, with two grooves upon it, fitted on a stud or pin in the underside of the frame, between the two wheels 1 and 2. The use of this pulley, with its ropes, as we shall describe, is to make the whole carriage move parallel, or both ends equally, which, in a carriage of twenty feet long, requires some nicety. As the two wheels 1 and 2 cannot be placed very distant, and therefore give little steadiness to a carriage of such a great length, the parallelism is thus preserved: a rope, 6, is made fast at one end to a fixed part of the framing, then passes a quarter round the upper groove of the pulley 5, and runs along the whole length of the carriage, and turns a quarter round a similar pulley 7, *fig. 3*, and then goes forward parallel to its first direction, from 6 to 5, and is made fast to the frame in a similar position to 8, *fig. 2*, but at the farther end of the frame. In the same manner, another rope is fastened to the frame at 8, and making a quarter turn round the lower groove of the pulley 5, proceeds the whole length of the carriage, makes a quarter turn over the pulley 7, *fig. 3*, and proceeds parallel to the first direction, from 8 to 5, and is made fast to the frame in a similar position to 6, but at the opposite side of the frame. The two ropes cross each other in the centre of the carriage, and they always pass over opposite sides of the pulleys 5 and 7. Their effect, which is not easily explained without a separate figure on purpose, is to make the carriage move equally at both ends, for it must do this, unless one or other of the ropes slip upon the grooves of their respective pulleys 5 or 7, and this they will not do if strained tight. We have clearly stated the passage of the two ropes 6 and 8, and the mechanic who knows this, will readily see the manner of its operation, though it is difficult to explain it by words only.

We must now attend to the wheel-work for the rollers: a bevelled wheel *o*, fixed close behind the wheel M, on the main axis, turns another on the end of an inclined axis *p*, *fig. 2*, at the opposite end of which is another bevelled wheel, turning *q*, fixed on the extremity of the front roller; which being connected with the middle and back rollers by the same wheel-work as the throttle frame, and the rollers being of a similar construction, demand no further description, except what we have already given in *fig. 4*, of the weights for pressing down the upper rollers. When the rollers are to be cast out of gear, it is done by disengaging the wheel, *p*, from the wheel *o*; for which purpose the bearing for the upper end of the inclined axis carrying the former, is made in the upper end of a lever *r*, which moves on a centre pin, fixed in the standard supporting the bearings for the axis of the wheel M: the lower end of this lever is connected with the end of a short lever *s*, moveable on a vertical centre pin fixed in the frame: this lever has an arm proceeding from the centre at right angles with that seen in *fig. 2*, and is therefore hidden behind the centre, its form being shewn at Z, which is a plan of this lever. From this second arm a wire proceeds to the pendulous lever P *t* *v*, moveable on the centre pin *t*. Now by moving the end, P, of the lever, P *t*, away from the wheel, M, it draws the wire and arm of the lever *s*, the other arm of which acting upon the lower end of the lever *r*, to throw it inwards, throws the upper end outwards, and brings the wheel, *p*, in contact with the wheel *o*, so that the inclined axis, and the front rollers also, are set in motion, as long as the end of lever, P, is kept held towards the end of the

frame. This holding is performed by its arm *v*, which, as in the figure, may be hooked under and kept down by a small catch *w*, and from this a fine wire, *g*, proceeds back to the opposite end of the frame, and is then linked to a short lever, which is fitted loosely on the same centre pin which connects the lower end of the lever, *r*, with the arm of the lever *s*. This lever is shewn at *z*, in the separate figure Z, but its use is only to support the end of the wire *g*, and keep it up, so that a part of the carriage of spindles, in running back, may, by intercepting the end of it, draw the wire and the catch *w*, thus relieving the arm, *v*, of the lever P, and this, as before explained, throws the wheel, *p*, out of gear, and the motion of the rollers ceases. On the return of the carriage towards the rollers, a piece of wood, *x*, fixed to it, runs against the lower end of P, and moves it back so far that the catch, *w*, engages it. This sets the rollers in motion, which they continue, until, in the retreat of the carriage, a piece of iron *y*, *fig. 1*, projecting up from it, catches the short lever, *z*, near *s*, supporting the wire *g*, which being thus drawn, disengages the catch *w*, and then the wheel, *p*, is cast out of the gear with *o*, as before-mentioned, and stops the motion of the rollers. The motion for drawing out the carriage from the rollers is thus performed: a cog-wheel R, which has a pulley fixed on against it, receives an endless rope, 10, passing round a pulley, 11, at the end of the frame. One part of the endless rope is tied to an iron arm projecting from the carriage, so that when the wheel, R, is turned round, by engaging its teeth with a cog-wheel fixed upon the end of the front roller, the endless rope, 10, traverses, and moves or draws the carriage out with it. The wheel R, which is called the Mendoza wheel, is made to lock in or out, by fitting it on a centre pin, which is fastened into the upper end of a lever T, (see the separate view,) moveable on a pin fixed in the frame. The lower end of this lever is moved by a horizontal lever, seen endways near V, which represents its vertical centre pin or stud. The end of this lever, which is before the stud, or nearest the eye, is connected by a strong wire with the lever P, and therefore, when this lever is pushed by the motion of the carriage, it engages the Mendoza wheel, and draws out the carriage, at the same time that the rollers are put in motion, and give out the roving between them; but the carriage, being drawn out to the length of roving which it is to have to stretch and spin the Mendoza wheel, is not disengaged the moment the rollers are cast out by the wire *g* and catch *w*, in the manner we have just described, because the lever, T, carrying that wheel is provided with a catch, similar in its properties to *w*, that is, it holds the wheel, R, in its work until the carriage has run a yard and a half, and then it seizes a wire communicating with this catch, thus disengaging the catch holding up the lever T: the Mendoza wheel then falls back, and the drawing-out movement of the spindles ceases. This catch and wire are not shewn in the figures, as it would produce much confusion, but being so exactly similar in this action to the catch *w*, and its wire *g*, they may be easily imagined.

We have now to describe the manner in which the rotation of the spindles is cast in and out. The reader, if not confuted by the complication of this machine, may remember that we explained the connection from the wheel M, by means of the endless cord *i*, to the wheel *m*, and thence to the vertical drum turning the spindles. When this motion is to be thrown in and out, it is done by shifting the main strap, driving the whole machine on the live or dead pulley K, *fig. 3*. The strap is guided by passing through an eye or loop at the extremity of a lever, W Y, fixed on a

vertical axis 12. On the lower end of this axis is a long lever 13, and at right angles to this a shorter lever, which being seen endways is not apparent, but it advances some distance forwards from the centre of the lever, and has a wire, 14, jointed to it, which is extended to a lever 15, against which the carriage runs when it is pushed home, and the spindles are close up to the front rollers. When this happens it draws the wire 14, which acting on the short lever of the axis, 12, turns it round, and the lever Y W with it, shifting the main strap from the dead to the live pulley K, and thus putting the whole machine in motion; at the same time that, by the operation we have before explained, the Mendoza wheel is thrown in, and also the movement of the rollers. The former of these draws back the carriage, till, as described, the catches are released, and the movement, first of the rollers, and then of the Mendoza wheel, are thrown out. At the moment before this happens, the carriage intercepts the end of the lever 13, which is formed like an inclined plane: it is therefore thrown outwards by the carriage running against it, and the end of the lever, W, being at the same time moved, it shifts the strap upon the dead pulley, and the motion of the whole machine ceases. The attendant to the machine now takes hold of the handle L, and pushes the whole carriage back again, till the spindle comes close home to the rollers; then by the carriage striking the levers 15 and P, it shifts the strap to the live pulley, and puts the spindles all in motion together, at the same time casts, in the motion of the rollers, to give out the roving; and also it casts in the Mendoza wheel, which traverses back the carriage and all the spindles to take up the roving as fast as it comes from the rollers, twisting it by the motion of the spindles all the time.

To describe the operation of this ingeniously constructed machine, will be only to recapitulate movements which we have repeated several times over; but this recapitulation will give the order in which they succeed each other. The man or woman who attends the mule stands in front of the spindles, at such a distance from the right-hand end of the frame that he can conveniently reach the handle L. In the other hand he holds the axis, I, of the wire H. Suppose, to commence, that the spindles are close to the rollers, then the movements succeed each other as follow:

1. The lever 15, being thrust back by the carriage running against it, draws the wire 14, and by the lever, W, shifts the strap upon the live pulley, putting the wheel M, and the wheels k, l, with the endless rope i, the wheel m, and all the spindles in motion.

2. The end of the lever, P, being pressed by the carriage, engages the wheel for the motion of the rollers, and they begin to deliver out the roving at the same time.

3. The Mendoza wheel is cast into gear, and begins to cause the carriage to retreat from the rollers as fast as they give out the roving. These first, second, and third motions, all happen at the same instant.

4. The spinning of the rovings is now performed by the above motions, the spindles twisting the rovings as fast as they are given out; but the motion of the rollers is so quick, that the twist now given is slight, but having thus extended, or taken out, a yard in length from each spindle to the roller, the piece of iron y, *fig. 1*, on the carriage, meets the end of the lever s, and

5. Disengages the wheel-work for the rollers, which are therefore stopped, and deliver out no more roving; but the retreat of the carriage and the twine of the spindles continues for another half yard, stretching out the thread, and twisting it, till the piece of iron, y, meets the catch of the next wire, which is not drawn in the figure, and

6. Disengages the Mendoza wheel, consequently the carriage draws out no farther. The thread being sufficiently extended and twitted,

7. The carriage takes hold of the end of the lever 13, and thus shifts the strap to the dead pulley K, *fig. 3*, and the motion of the whole machine ceases.

8. The attendant, by turning round the axis, I, of the wire H, presses down all the threads together from the points of the spindles to the middle of the coppin, in the manner of *fig. 5*; then

9. Takes hold of the winch L, to regulate the winding of the thread on the coppins, when he

10. Drives the carriage home to the rollers. In this motion the spindles all revolve, and lap up the thread upon the coppin. The revolution is caused by the endless rope i, which may, when the machine is standing still, be considered as a stationary rope acting upon the wheel m. and the drum for the spindles, and as their centres traverse, turning them all round, on the same principle as a carriage wheel is turned by rolling on the stationary road. In like manner m is turned, by moving along while the rope, i, is immovable. Now the quantity of motion, or the number of revolutions the spindles will make during this return of the carriage, is, in all cases, the same, and the quantity of thread to be wound up is always the same; but it is evident that it will require a greater number of revolutions to wind up the length (1 $\frac{1}{2}$ yard) of thread, when winding upon the spindle, or upon the circumference of a small coppin, than when the same coppin is increased by the accumulated thread to ten or fifteen times the size of the spindle. To accommodate this, it is necessary for the spinner to have the handle, L, in his hand, because he can, by turning this one way or the other, add or diminish so much to the number of turns the spindle will make, as will just take up the thread as fast as the carriage advances towards the rollers. Thus, at first beginning, when the coppins are small, the handle, L, will require to be turned forwards a considerable quantity, to make them wind up the thread sufficiently fast; but as the size of the coppins increase, they will come to such a diameter, that the handle requires to be held quite still. The motion given to the spindles by the return of the carriage, being then just equal to wind up the thread at the proper rate, any increase of the dimensions of the coppins after this will require the handle, L, to be turned backwards, to diminish the motion of the spindles, or they would wind up too fast, and break the threads.

The spinner accommodates the motion of the handle, L, so exactly by habit, as to keep the threads always to that degree of tension as will make the coppin compact, but not injure the thread; at the same time by the other hand, which holds the spindle of the wire H, he lays the thread regularly on the length of the coppin.

The carriage, having with these precautions been wheeled up close to the rollers, the several operations are repeated as before; and thus the mule continues to spin a yard and a half upon each spindle every time it is drawn out, and then wind it up on the several coppins. A good spinner will draw out 3000 times per day of a mule with 240 spindles; and many women will attend two machines, having them placed opposite to each other; and while one is drawing out she will thrust home the other. This makes 108,000 yards per day upon each mule, or both together will make more than 1200 miles to be spun in one day by one woman; who, on the old method of the hand-wheel spinning, on which the mule is an improvement, would only have managed single spindle, instead of 480; and this single spindle would not have spun half the quantity of any one in the mule; and

with respect to the regularity and accuracy of the thread no comparison can be drawn. A mule of 240 spindles has nine drums in the carriage to turn them; all the length, therefore, is nine repetitions of *fig. 3*, which only contains the spindles turned by one drum.

The motion of the mule can at any time be stopped, if a thread break, or any other accident happens, by means of a long wooden rail, *Y*, which is joined to the end of the lever *W Y*, and extends along over the whole length of the rollers, so as to give the spinner the means of stopping the mule when standing opposite to any part of its length; for it is evident, that by thrusting this rod one way or the other, the strap will be shifted either on the live or the dead pulley, stopping or putting the wheels in motion at pleasure.

The thread spun upon the mule is much softer, and has a smoother surface than the water-twist: this is owing to the manner in which the extension of the thread is made, after it has been twisted slightly, and the fibres thereby compressed together in some degree; for the effect of stretching a slightly twisted thread is, to draw all the ends of the fibres into it. All these fibres having assumed a spirally curved form in the thread, by drawing or stretching them out in the length of the thread one among another, these fibres are drawn along with a spiral movement, and all their ends are thus brought into, and concealed in the body of the thread. This operation, at the same time it makes the surface of the thread even and smooth from projecting fibres, increases the strength of the thread by bringing them all into use; and the strength obtained by this means does not require the thread to be twisted hard, but leaves it soft and pliable, which is the great recommendation of the mule-twist.

The thread thus spun, either by the water-frame or mule, has many other operations to go through to prepare it for the market, where it is to be sold to the weaver or manufacturer. The chief end of these operations is, measuring it out in lengths, weighing it to ascertain the number, and packing it up for carriage. The first machine the thread is taken to after spinning is

The Reel; see *figs. 1* and *2* of *Plate XII*. The former being an elevation of the end, and the other an elevation in front, a very short explanation of this machine will suffice; its framing and some other parts being evident. *A A* is a row of the bobbins of the spinning frame, or for mule-twist, the coppins of the mule stuck upon pins, on which they will revolve freely and give off their thread. *B*, *fig. 1*, is another row placed behind the former, and arranged in the intermediate spaces between the bobbins of the first row, which arrangement is necessary, because the bobbins would touch each other if all placed side by side. The threads for these bobbins are conducted between several pins or wires, stuck up in a rail of wood *D*, and each thread is twisted once round one of these pins, that it may be drawn off with such a degree of force, from the friction thus occasioned, as will cause the thread to lap or wind with a sufficient tension upon the reel *E E*, which consists of a horizontal shaft *E*, from which three sets of arms, *F*, proceed, supporting six rails, *G, G*, parallel to the axis, and upon these the thread is wound, as shewn in the figures at *r*. The dimensions of the reel is such, that it takes exactly a yard and a half of thread to make one turn round it: this, therefore, is the measure of length, and the mechanism which remains to be described is for the purpose of counting the number of revolutions it has made. The reel is turned round by means of a cog-wheel, *H*, on the end of the spindle: this is turned round by a wheel *K*, on the

axis of which is a pulley *M*, to receive an endless rope, which is turned round by the mill; but the bearing for the pivot of the axis, *E*, is fitted in a groove, formed on the top rail of the frame, so that the wheel, *H*, may, by sliding the bearing in this groove, be disengaged from the teeth of the wheel *K*, and then the movement being thrown out of gear, the reel stops. On the opposite end of the axis of the reel, a pinion, *a*, of 14 teeth is fixed, which turns a bevelled wheel of 28 teeth on the upper end of a vertical axis *b*, which has an endless screw upon it, turning a wheel, *d*, *fig. 1*, of 40 teeth, on the axis of which is a pinion of eight leaves, turning a wheel, *e*, of 56 teeth. This wheel has a small circular ring fixed on the face of it, which is formed like a snail on the front edge, that is, its surface is not parallel to the plane of the wheel, but is inclined to it in such an angle, that in turning round it operates upon a lever, *f*, to move it backwards and forwards, and this motion is, by means of a vertical lever, *h h*, communicated to the rails, *A B* and *D*, at the top of the reel, which carry the bobbins, and also the pins, *D*, that guide the thread, and having thus a short traverse motion parallel to the axis of the reel, the threads are laid regularly by the side of each other, without overlaying each other in one place, as they would do without this motion, and by thus enlarging the diameter of the reel, the thread that winds upon the measure would be incorrect.

By calculating the numbers of the train of wheel-work, *a, b, d*, &c. which we have before explained, *viz.* by multiplying the number of all the pinions together, and the number of all the wheels together, and dividing one sum by the other, thus, $14 \times 1 \times 8 = 112$, the product of all the pinions: again, $28 \times 40 \times 56 = 62,720$, the product of the wheels. Divide 62,720 by 112, and the result is 560; therefore the wheel *e*, of 56 teeth, will make one turn for 560 turns, or bouts of the reel. The wheel *d* makes only one-seventh of this number, or once for 80 bouts; and a pin being fixed in the back of its rim, seizes the tail of a bell, *m*, once for every turn it makes, consequently this bell rings at every 80 bouts of a yard and a half each, = 120 yards of thread wound upon the reel. The reeler, in beginning, makes the end of each thread fast to one of the rails, *G*, of the reel, then casts it on, and sets it going until the bell, *m*, rings; it will then have made 80 bouts, or reeled; 20 yards, which is called a ley. The reel is stopped the instant the bell rings, and every one of the leys of thread, *r, r*, *fig. 2*, is tied up by a piece of thread to keep these 80 bouts distinct; then the reel is set on again and another ley reeled, which is tied in its turn; and when seven leys have been thus done, it makes 560 bouts, or 840 yards, which length is called a hank: the seven leys composing it are tied all together, the ends of the thread cut off, and the hanks are removed from the reel. They are got off by what is called striking the reel, to do which, the arms supporting one of the rails, *G*, are divided across in the middle of each, and united by hinges. When the arms are set straight, and kept so by a small bolt, the reel is of the true dimensions; but by withdrawing the bolt, and bending the arms on the hinges, the rail falls in towards the centre, and the reel is so diminished in size, that the hanks hang slack upon it, and can easily be slipped off at the end of the reel, which is lifted off its bearings for that purpose.

A reel usually winds 50 bobbins at once, and the principal care of the attendant is to watch the bobbins, supplying others, and tying the ends of the threads as fast as they are exhausted.

The hanks are now twisted up into a knot, by catching one end of them over an iron hook fixed to the wall, then put-

ting a small iron rod in the other end, the hank is twisted up very hard, using the rod as a lever to turn it round. To prevent its untwisting again, it is taken by the middle of its length, and without suffering the ends to entwine it is doubled, then the ends are released, and the two halves twist over each other, forming a bundle or knot of thread, resembling a piece of thick rope, about eight or nine inches in length, and perhaps two inches girth. The hanks, being thus all knotted, are weighed, to ascertain their number. The weighing instrument consists of a short pendulum, from which an arm proceeds on each side, at top passing through the centre of suspension, so that it resembles the letter T. From one of the horizontal arms a hook is suspended, by which the hank is hung on; and at the end of the other arm is an index pointing to an arch which is divided, and has figures upon it, shewing how many of such hanks (as the index is brought to by hanging any one upon the hook) will weigh a pound. The divisions are made by experiment, and frequently verified by means of small leaden weights, which the overseer is provided with.

As fast as the number of the several hanks is determined by this index, they are thrown into different bins or shelves, and when they are to be made up for market, as many hanks of any number as will weigh ten pounds are counted out, weighed, as a check upon the weighing instrument, and packed up in paper, forming a small square bundle, which is made compact and tight in the bundling-press. This is a small square chest, of about eight and a half inches by nine and a half, formed of vertical iron bars set upon a table, and a lid of iron bars shuts down over the top, with bolts or other fastenings. The bottom of the chest is moveable up and down by means of a rack and pinion, a screw or other means, which will enable the workman to give a great pressure upwards. The hanks are packed closely into this chest with paper round them, and the whole number being packed in, the lid is shut down and bolted upon them; then by turning a handle the bottom of the press is raised up, and compresses the bundle together into as small a compass as is required. The bundle in this state is tied round with several strings, the interstices between the iron bars composing the press leaving sufficient room for the admission of such strings, and for the knots to be tied to confine the bundle. In these bundles the greatest portion of the twist is sent to market; but what is called hard twist, must be twisted two threads together, as is also stocking-yarn. Such thread as is intended to be doubled for these purposes, is taken from the spinning-frame to the

Doubling machine, instead of the reel. Here the threads, two together, are wound upon bobbins, as preparatory to twisting them round each other. See *Plate XIII.*, *figs. 1* and *2*, which represent a doubling mill; in front *fig. 1*, and endways at *fig. 2*. A is the pulley which is turned round by the mill: this pulley is loose on its spindle, but has a clutch or locking-box at the back which connects it with its spindle, when the upper end of the lever, B, is moved towards the machine. But when it is moved the other way the machine stands still, though the pulley continues all the time to turn round. A wedge, *a*, being put on either side of the lever in its mortise through the piece of wood D, retains the pulley, A, either unlocked or locked in gear, with the spindle which is fixed in the end of a throttle-cylinder, R, and by bands turns all the spindles, *b, b*, together. The bobbins of the spinning-frame are stuck upon pins in the top rail, E, of the frame, and the threads descend to wires, *d*, round which they make a turn, two threads in company, to produce a friction, as before explained, sufficient to lay the turns on the bobbin of the spindles, *b, b*,

tight and even. The threads then go through wire staples or eyes fixed in a rail, F, situated opposite to the bobbins *e, e*, which are stuck fast on the upper ends of the spindles *b, b*, and being turned thereby, wind up the thread from the bobbins at E: the rail, F, is adapted to rise and fall parallel to itself, being attached by radial bars to an axis moving on centre pins fixed in the frame. Its motion is occasioned by an iron rod, *f*, which is jointed to it, and connects it to a lever, *g*, fixed on an axis; and at the extreme end of this is a lever, *h*, *fig. 2*, resting upon the circumference of a heart, *h*, fixed on the face of a cog-wheel *i*. This is turned by a pinion fixed against a wheel *k*, which receives its motion from another pinion upon the end of the spindle of the throttle cylinder R. By this train of wheel-work the heart is slowly turned round, and raises and falls the lever, *h*, at the same time giving a similar motion to the rail F, and by that means regularly winding the thread upon the bobbins *e, e*, which are turned rapidly round by the motion of the vertical spindles *b, b*, which receive their motion from the throttle cylinder, R, by the bands, as before described. The bobbins are such as shewn separate at X, and have a hole through them exactly fitting the conical end of the spindle, on which it sticks so fast, that the bobbin will, by the motion of the spindle, wind up the two threads together off the bobbins at E. When the bobbins are filled with double thread, they are removed to the twisting-machine, if it is intended to make stocking-yarn, or if it is to be what is called hard twist, for sewing, knitting, or mending-cotton, it is done in the water-frame, which, however, undergoes some alterations, *viz.* the spindles are made to turn about in a contrary direction to that in which they moved to spin the thread. It is done by turning the whole frame the other way about, but as this would make the rollers move the wrong way, the pinion at the upper end of the spindle of the binder is placed at the outside instead of the inside of the face-wheel on the end of the front roller. The rollers then turn the right way about to deliver the thread to the spindle, but the back and middle rollers are removed, as it is not required to draw out the thread, the rollers being merely wanted to hold the threads fast whilst they are twisted one about the other, and to deliver it regularly to the spindle, which operates in the same manner as for the first spinning, except that it twists in the contrary direction; because when any two threads are to be turned together, it must be done by a contrary twist to that which composed the two separate threads themselves. After spinning this hard twist it goes to the reel, and is treated in all respects as other twist is. When it is merely required to twine the two threads slightly together for stocking-yarn, the bobbins of the doubling-machine, when filled with double threads, are carried away to

The twisting-machine, see *Plate XIII.*, *fig. 3*, of which is an elevation endways; and *fig. 4*, another elevation taken in front. In this, A represents the live and dead pulleys turning the whole machine: the strap is conducted through an eye at the end of an iron branch *a*, affixed to a rod or beam B, which slides in guides beneath the machine, and can be moved endways by means of a lever *b*, which comes out in the middle of the length of the machine, and the attendant, by applying his foot to this lever, and moving it sideways, shifts the beam B, and the eye at the end of the branch, *a*, guides the strap upon the dead pulley: the machine then stands still. The live and dead pulley is fitted on the end of the spindle of the throttle cylinder D, which, by bands going to both sides, turns a double row of vertical spindles on each side, E *e* and F *f*, the internal row on either side being placed opposite the spaces between the outer row, so that

the spindles are not crowded too close together. On these spindles the bobbins are stuck in the same manner as those of the doubling-mill; and the threads proceeding from the bobbins are conducted through wire eyes, which are fixed in rails, G, of the framing, then each twisted thread makes a turn round a wire fixed in the rails, H, just above G, and these have a slight traverse motion backwards and forwards, by which they lay the thread evenly upon the reels, I, K, which take up the threads, as before described, of the reeling-machine. The reels are slowly turned round by a train of wheel-work from the main spindle of the pulley A. This train consists, first, of a pair of bevelled wheels, one on the main axis, and the other at the lower end of a vertical spindle L, which at the upper end has a pinion actuating another wheel, g, upon the middle of a horizontal axis, which at each end carries a pinion, turning wheels; M, N, on the ends of the pivots of the two reels. The proportions of the wheels are such, that the reel turns once for about 24 turns of the main throstle D, or about one for every 72 revolutions of the spindles, and as the reel is a yard and a half about, the thread will be twisted about 72 times in that length by the rotation of the bobbin and the thread with it. The motion of the reel draws the thread off the bobbin as fast as above-mentioned, so that the proportion of the wheel-work determines the quantity of twist which shall be given in any certain length. The reels are provided with counting wheel-work of the same operation as that before explained in the reeling-machine. Thus, on the end of the spindle of the reel is a pinion turning a wheel *i*, on the axis of which is a screw turning a wheel *k*, and this has a pinion on it turning a wheel *m*, by means of the intermediate wheel *l*. The spindle of this latter wheel has a nail fixed upon it, which operates upon a lever *n*, the lower end of which presses against a cross-bar, connecting the rail, H, with its fellow. On the opposite side of the machine there is another similar cross-bar at the other end, and the two rails being thus united, form a frame which is supported on iron radial bars *p, p*, which move upon centre pins fixed in the rail, G, of the frame; so that the frame, with the rails H, H, has a free motion to traverse without friction, and guide the threads to lay regularly upon the reels I, K. At the opposite end of the frame a string is tied which passes over a pulley, and has a weight, *r*, suspended from it, which always draws the frame one way, and tends to keep the upper end of the lever, *n*, in contact with the snail upon the axis of the wheel *m*. This axis has also a pin projecting from it, which every time the spindle turns round, rings the bell P. The motion of the wheel-work is so calculated, that the bell shall ring once for every 280 bouts of the reel, and the size thereof is such, that this 280 bouts shall measure 420 yards, being the length of the double thread hank, *r*, equal to half the length of the single thread hank, which is, as before mentioned, 840 yards, and the number of double thread yarn, is according to the number of these hanks of 420 yards each to the pound. The reels, I, K, when filled, are struck, and the hanks taken off them in the same manner as the reeling-machine before described.

Hard twist, which is intended for sewing, knitting, or mending-cotton, after being twisted and reeled in hanks, is sent to the bleach-field, and bleached by some of the processes described in our article BLEACHING.

But the process which is most generally in use for bleaching yarn, is thus conducted: an earthen-ware retort is filled with one quart of oil of vitriol, two quarts of sea-salt, and one quart of the ore of manganese. The hood of the retort being put on and luted, it is set over a small

stove or sand-bath, and the heat soon raises from it the oxygenated muriatic acid gas, which is received in a square wooden chest, about seven or eight feet square, and as many deep, forming a small air-tight chamber, in the upper part of which the goods are suspended upon a rack or frame. The lower part of the chest, for about three feet deep, is filled with water, sometimes impregnated with a ley of pot-ash, and sometimes with lime-water, or water mixed with lime. The gas is introduced betwixt the fluid and the goods, amongst which it ascends, and by its action upon any colour they may contain, renders them white: at the same time, by occasionally immersing the goods in the fluid below, it is sought to modify the action of the acid, and prevent the operation proceeding too rapidly. This is effected by means of a pole or long rod connected with the frame on which the goods are suspended, the centre of which pole moves on a swivel fixed in a hole in the partition, or lid of the chamber, which is occasionally stopped with clay, and enables a person to raise the goods by means of a small crane, or, at pleasure, to let them down into the fluid, not always, however, without inconvenience, which occasioned it the name of the *Bedlam process*, as the workmen, if they inhale the gas, are stupified.

Previously to the yarn being subjected to the action of the gas, it is boiled in a ley of pearl-ashes, then milled for twenty minutes in a fulling mill, and the hanks are hung upon the racks or cross rails of the square frame in which they are suspended, to be let down into the bleaching-chamber. This frame is, as before-mentioned, attached to a long pole, that suspends it from the crane, which being swung over the chamber, is let down therein, and the lid is closed over it, the joints being made tight with clay, and the pole coming through a hole in the lid, which is carefully made tight round it by a wet cloth. The gas is now admitted to the chamber, but the yarn is not subjected to its action more than ten minutes before it is let down and immersed into the liquor at the bottom of it, which thus defends it from the action of the gas for a few minutes, until it becomes thoroughly wetted, when it is drawn up again into the gas, and remains in it for half an hour to be bleached: it is then let down again, for a few minutes, into the liquor to wet it; it is then drawn up again, and in this manner the process continues, until such time as it is known, by experience, that the yarn will be sufficiently bleached. The frame is drawn up by the crane, and the cotton removed from the rails on which it hangs, and being rinsed in clean water, is carried out and spread on the grafs in the fields, to be subjected to the sun and air, by which the bleaching is completed. It is not the business of the present article to enter into the theory or chemical principles of this process, which will be found under the article BLEACHING.

After the hanks are returned bleached, the yarn is found to be much lighter, so that it will generally be two numbers higher: thus, cotton of N^o 48 hanks to the pound being sent to bleach, will return so much diminished in weight, as to require 50 of the hanks to weigh a pound. But this rule is not so exact as is requisite; the thread must therefore be reeled over again, weighed, and packed. A great proportion of the sewing cotton is wound into balls of a very beautiful appearance by a curious winding machine. As a preparation to this winding, the thread must be wound off the hanks in which it was bleached to large bobbins. This is done in a machine provided with several spindles, like the doubling machine, upon which bobbins are stuck, and the thread wound on them from the hanks, when they are extended or stretched out between two pul-

Reels, or small reels, on which the hank revolves in the manner of an endless band. These bobbins are taken to the

Ball Winding Machine, see *figs. 3. and 4. of Plate XII.* the former being a plan of the acting parts, and the latter an elevation of the whole machine on a smaller scale. In *fig. 4.* A is the bobbin from the winding machine, which is stuck upon a pin projecting upwards from the bench, and a small lead weight is laid upon the top of the bobbin, to load it, and cause such a friction as will make the thread wind with a proper tension upon the ball. The principal part of the machine is a spindle B, which is perforated through its length, and receives the thread: it runs, in bearings, at the top of two standards *a, b*, and at the extreme end of the spindle, beyond the front standard, a flyer or branch, D, is fixed, and the end, *d*, of it therefore describes a circle when the spindle, B, turns round by the endless band which surrounds the pulley E, and gives it motion from the mill. The spindle has an endless screw cut upon it, turning a wheel, G, at the upper end of the vertical spindle F, which, at the lower end, has an universal joint, *e*, connecting it with an inclined spindle H: this, at the lower end, has a small bevelled wheel, *b*, turning another, *f*, on a small vertical axis, carrying, at the upper end, an universal joint, which communicates motion to an inclined spindle I, and this, by another similar joint at *i*, connects with a vertical axis *r*, which has a pinion, *k*, turning a wheel *l*, upon whose spindle, *m*, the thread is lapped to form the ball, as shewn in *fig. 3*: the spindle, *m*, is supported by a piece of metal, K, formed like the letter L, and moveable on a centre pin *n*, which is situated exactly in a line with the short vertical axis of the wheel *f*: M is a circular plate, on which the piece, K, rests, when turned about on its centre pin *n*, and N is the handle by which it is turned about at pleasure upon it. The two spindles, B and *m*, are, as shewn in *fig. 4*, on the same level, but are capable, as shewn in *fig. 3*, of being set at any angle to each other by inclining *m* on its centre pin *n*, and this being in the line of the spindle of *f*, the motion does not tend to lengthen or shorten the spindles I and *r*; but they always convey the motion, communicated from the spindle, B, by means of the axes F H I and *r*, to *m*, by the several wheels G, *b*, *f*, *k*, and *l*, which have been described: they are so apportioned, that the spindle, *m*, turns only once for 48, 60, or 72 revolutions of the spindle B. These different numbers are used in different machines, and the appearance of the ball they will wind materially depends upon this circumstance.

To explain its operation, suppose the spindle, *m*, inclined to B, as in *fig. 3*, the rapid motion of the spindle, and its flyer D, (over the point, *d*, of which the thread is conducted) laps the thread round the spindle, *m*, in an oblique direction. At first, the ball thus formed has no regular figure, but as the thread accumulates and forms a cone, the lapping of the thread in a regular order begins and continues, as in *fig. 3*; here it is seen, that the motion of the flyer will lap the thread obliquely upon the ball from one end to the other, as the figure shews; but at every succeeding revolution of the flyer, the ball itself has made $\frac{1}{48}$, $\frac{1}{60}$, $\frac{1}{72}$, part of a revolution upon its own axis *m*, according to the proportion of the wheel-work, and thus the thread is not always disposed on the same oblique line, but on another parallel to it, and removed a small distance from the former. Now it is plain, that the thread on the underside of the ball must be inclined in a contrary direction to that lapped on the upper side; therefore, when the ball is looked at, the oblique threads of every alternate layer cross each other, in the manner of the figure. This will, however, be much

more readily understood from an inspection of a ball of this kind, than from any verbal description. The length of the ball depends upon the angle which the spindle, *m*, makes with the spindle B; it can, therefore, by shifting the handle N, be wound off of any required figure; but the most general method is, when about one half the size of the ball is wound, to give the spindle a greater degree of obliquity: this occasions the ball to wind longer from that period, as well as a greater diameter: the consequence is, that when the ball is finished, on looking at the end of it a circular hollow is seen in it, as though it had been turned in a lathe, and sometimes a thin membrane, consisting of about two or three layers of thread, is extended nearly across the end, leaving the hollow beneath, which can be seen into from a small hole in the end. This membrane is made by setting the handle, N, at the greatest angle it will make, the thread then not only lays over the whole surface of the ball, but is stretched partly across the end of it; and the intersection of a great number of these forms a transparent membrane, which has a circular hole in the centre. After laying this layer two or three times over, the handle, N, is returned to its original angle, and winds the ball as at first.

The bench or table R R, on which the machine stands, is made long enough to contain fourteen spindles, all placed in one row; and a throttle cylinder, running along under the bench, gives motion to them all at once. Two children attend the whole fourteen, which they can readily do, having only to lap the thread, at the beginning, upon the spindle *m*, and then, when the ball has arrived at a certain size, to turn the handle N; but the period or quantity of this alteration is not of any great importance, as it only influences the figure of the ball, and, as we before described, those fancy ornaments within the hollow end: these may, by great attention in frequently and artfully shifting the handle N, be made very delicate and beautiful. The machine we have just described was made after a model of a machine invented by Mr. Brunell, who first devised the means of connecting the spindles, B and *m*, by wheel-work. The machines, before this, were turned by endless bands, from the principal cylinder which gave motion to the whole. The defect of this method was, that the relative diameters of the wheels could not be so exactly proportioned, as to produce one turn of *m* for exactly forty-eight, &c. of B; that the threads of the successive layers would lay exactly one over the other, because the least variation in this respect would greatly injure the effect of the ball. But in the machine before us, the motions are so accurate, that, on inspecting the ball, it appears honey-combed, or consisting of regular cells, which gradually diminish in size as they approach the centre: the partitions between these cells are only one thread in thickness, but consisting of a great number, stretched so exactly over each other, that they form regular plane sides to the interior of the several cells.

We have now presented our readers with all the operations of cotton-spinning; but these operations are conducted on so grand a scale by many manufacturers, that the system of their management, the arrangement of the buildings, the construction of their water-wheels, steam-engines, or other first movers, and many other particulars, are no less admirable, and worthy of description, than the machines themselves. To describe all these curiosities of the cotton trade would fill a volume; but we must content ourselves with describing one plate, which contains drawings of one of the most complete cotton-mills we have ever visited. It is one of the four mills at Belper, in Derbyshire, belonging to Messrs. Strutts, whose very extensive works contain almost every improvement in the cotton trade. The whole of

these mills is built fire-proof, being without any timber beams in the floors, or much wood work of large size in any of the machines, which makes them very secure from danger by fire.

Fig. 1. of *Plate XIV.* is a longitudinal section of the whole mill, shewing all the floors, and all the machines upon them, at one view. *Fig. 2.* is a section, across the length of the former; and *fig. 3.* is a similar cross section of the mill, and, at the same time, a longitudinal section of the wing, which extends from the centre of the mill, at right angles, to its length; so that the plan of the mill is of the figure of the letter T. We will first explain the manner of building fire-proof mills without timber, which has been adopted by Messrs. Strutts in their very extensive works.

The side walls A A, B B, and the end walls C C, D D, are built up as usual, and with the usual doors and windows in them; the several floors, E, F, G, H, I, K, are composed of brick arches, as shewn in the figures. In *fig. 1.*, these arches are shewn cut across the span; and in *fig. 2.*, they are shewn cut through the crown, parallel to the axis. These arches have a very small rise, and their span is nine feet from one to the next. The abutments, or springings of the arches, are supported by iron columns, *a, a*, as shewn in the figures, which are erected, one upon another, in the several floors, through the whole height of the mill. They are connected by cast-iron beams or girders, *b, b*, shewn in *fig. 2.*, one of which extends from the top of every column to the next, and forms a support or springing for the arches. In an opposite direction to these girders, every pair of the columns, *a, a*, are tied together, across the arch, by a wrought iron bar, which has an eye at each end, to be hooked over the tops of the columns, and keep them tied together, resisting the lateral thrust of the arch, and preventing the columns from being thrust asunder from each other, as they would otherwise be. Thus, though every floor is formed of a system of arches, like a bridge, as shewn in *fig. 1.*, yet the lateral strain of each is supported by iron ties; so that each arch stands by its own supports, independent of its neighbours. The arches are of only one brick thickness, and are covered over at top by a floor of paving bricks, to make a flat surface above, the haunches of the arches being filled up by rubbish. The iron ties across the arches are concealed within the brick-work of the arch, so that they do not appear; the ceilings of the rooms, therefore, consist of regular arches, which have a very good appearance, and make the most firm and solid floors above that can be imagined. The roof is of cast-iron, as shewn in *fig. 2.*, where the two columns, *d, d*, are a continuation of the columns, *a, a*, in the lower floors; and a cross or girder beam, *e*, which connects them, is also a support of the cast-iron principals, *f, f*, of the roof; and *g, g*, are further stays, proceeding from the iron girders uniting the columns of the ceiling, *b*, beneath: the space between the two columns, *d, d*, in the roof, forms a small room, which is used as a school-room for the work-people on Sundays. The desks and forms are shewn in the figure.

The mill contains fifteen arches in length, as shewn in *fig. 1.* between the walls C C, D D, which are the end walls of the mills. Besides these is another wall, L, to which the floors are continued by two additional arches, added beyond the end wall, C, of the mill. This space forms a small room on each floor, which is occupied by the counting-house, stair-case, and the stove, which warms the mill in winter, and also a crane of a peculiar construction, for drawing up the goods to the machines on the several floors.

The space of the mill, therefore, between the walls C

and D, is appropriated to the machinery, as is also the wing, which consists of six arches, as shewn in *fig. 3.*, projecting from the middle of the mill, perpendicular to its length.

The width both of the mill and the wing is, as shewn in *fig. 3.*, composed of three lengths of arches, having three iron girders that they rise from, and two columns to support them. The arches in the ground-floor, or cave of the mill, are supported by very strong piers, *m*, instead of iron columns. These piers are founded very firmly in the earth, and every caution taken to prevent them subsiding, or settling under the great weight they have to carry. The columns of the first floor are erected immediately upon the top of these piers: on the top of these columns are those for the second floor; the third surmount these, and so on to the top of the mill: the columns being thus erected, one upon another for the whole height of the mill, forms the staunchest building that can be imagined.

We shall now proceed to describe the machinery of the mill. The whole motion is taken from the great water-wheel M, situated underneath the wing, in the cave, or lowest room of the mill; and as it is of so great a size, namely, 18 feet diameter, and 23 feet long, that no cast-iron girder could be thrown across it strong enough to support the arches for the wing above it, a strong stone arch, N, is thrown across from the wall *b*, which is built up at one end of the water-wheel, to the wall, A, of the mill, which is at the other end of the mill; and to resist the thrust of this arch, two strong iron bolts, *x*, are extended across it, and render it as strong as possible; so that the iron columns of the wing over it may be raised upon it as safely as they could upon foundation piers, *m*, like the others. But as a precaution against overloading the walls, *b* and A, which, as they include the water-wheel, would ruin every thing, if they settled in the least, the arches of the wing immediately over the water-wheel are built, instead of solid brick, with small pots like garden pots, so that they are light, but sufficiently strong to bear any thing which is ever required to be loaded upon them. These small pots are also used to build the arched floor, K, of the roof, that it may be light, and as it has nothing to bear but the school room, they are sufficiently strong to make the floor.

The great water-wheel has a cog-wheel, *o*, upon the end of its shaft, which turns a pinion, *p*, on a strong shaft, that carries a wheel *q*, and thus turns a pinion on a third shaft, *r*: this, at the end, has a bevelled wheel, which gives motion to a vertical shaft, *s*, proceeding up to the top of the mill, and turning the machinery in the several floors. The bevelled wheel on the shaft, *r*, also drives a horizontal shaft, *t*, extending the whole length of the mill, and having upon it, just beneath every arch, a bevelled wheel, turning another on a vertical spindle, which rises up through the two floors D and G. These are the main spindles of the spinning frames, and the great frames are fixed upon them. The frames are all shewn endways in *fig. 1.*; but in *fig. 3.*, on the floor F, a pair of frames are shewn in front, as they stand side by side, and the floor, G, over it has just the same, as has also the wing, though not put in the drawing; but these last are turned by a bevelled wheel, *v*, *fig. 1.* on the shaft *s*, in the floor G, which turns a horizontal shaft, *v*, *fig. 3.*, extending the whole length of the wing, and turning the spindles of the several frames as it passes over them. The two lowest floors, F, G, which are appropriated to the spinning frames, contain 28 frames on each floor, 56 and 12 more in the two floors of the wing, in all containing 4236 spindles, a considerable proportion of which are, however, employed in spinning the hard twist. The two next floors, viz.

the 3d, H, and the 4th, I, are occupied in the body of the mill with carding machines, which stand in three rows: they are turned by straps from a horizontal shaft, extending the whole length of the mill, over the machines. In *fig. 1.* they are shewn endways, and *fig. 3.* shews them in front of the floor H, while that above it is just the same, though not drawn: in all these two floors are 64 breaking cards and 72 finishers. The same floors, H and I, in the wing, contain 16 drawing frames and four stretching frames or mules, in which the rovings are prepared as described in our account of the different methods of making rovings. The fifth floor, I, contains the reeling, doubling, and twisting machines, &c. as we have described; but the numbers of the different kinds of these last mentioned machines vary in every mill, according to the kind of cotton which is to be spun in it, and that branch of trade its proprietor intended to carry on: if it is for spinning twist for weavers, only reels will be wanted in the fifth floor; or if it is to spin stocking yarn, doubling and twisting machines will be wanted. Indeed these last machines are altered every few years in cotton mills, according as the state of the trade varies from a demand of one article to another.

The space of the mill, between the walls C and L, contains, as before-mentioned, the staircase O, which is of stone, ascending from one floor to the next, and also the crane P P. This is a most ingenious and useful machine, which has been adopted by Messrs. Strutts in all their cotton mills, and it is applicable to many other manufactories. The crane consists of a large square basket, or cradle, four feet six inches square in the bottom, withinside, and six feet deep: it is open in front. The bottom is a floor of wood, and the sides wicker or basket work strongly bound with iron straps. This basket or cradle is suspended by a rope in a well P, extending from the top to the bottom of the mill, through all its floors. The cradle exactly fills the well, and is guided by iron sliders in each angle, so that it may be steadily drawn up from one floor to any other by the power of the mill, and stopped or set in motion, either up or down, at pleasure, by pulling two guide ropes, which are always in reach of a little boy who sits at the top of the cradle in a seat made for the purpose. Now the machinery for effecting this is the only difficulty: it is necessary, in such a crane, that the machinery, when cast on to draw up the cradle, should move with a regular and equable velocity, without making any shock or jerk when it first starts; that it should stop the instant it is required, otherwise it would be very difficult to set the cradle, with its floor, exactly on a level with any of the floors of the mill, and if not so, it would be very inconvenient for the people to get in or out of it.

The cradle must also be let down by the power of the mill as well as drawn up, because if suffered to run down by its own weight, it would always run down too quick or too slow, and be dangerous and uncertain: it must, at the same time, be so contrived, that the cradle itself will stop the machine if drawn up too high, or let down too low, to prevent its being over-wound and breaking the works. All these conditions are effected, in the most perfect manner, by very ingenious mechanism, which was invented by Mr. H. Strutt, and has been adopted in all his father's mills, rendering these cranes as safe and manageable as possible. The rope suspending the cradle in the well is double, to ensure greater strength, and is conducted over a pulley, or grooved wheel, situated in the roof of the mill. The other end has such a weight suspended from it, as will balance the weight of the cradle, together with half the weight of the usual load the crane is expected to carry. This weight, therefore, draws the rope so tight upon the grooved wheel, that it will, by

turning round one way or the other, elevate or depress the cradle at pleasure, and at the same time the balance weight, which has a small well of its own to work in. The axis of the grooved wheel has a cog-wheel on the end of it, which is turned round by a small pinion fixed on the extremity of an axis on which the mechanism is placed: it consists, first, of a large wheel, like a coach wheel, shewn at *x*, *fig. 1.* fixed on the middle of the axis, and on each side of this are two broad riggers or drums to receive the endless straps, which give the motion against these riggers on the outside of each. A dead pulley or rigger is fitted loosely on the axis, and being exactly the same size as the live riggers or pullies, the strap can be shifted from one to the other in a moment. The axis is actuated by two endless straps coming from one drawn at *y*, *fig. 1.* which is turned by wheel-work from the shaft in the fifth floor of the mill, as the figure shews. One of these straps is crossed between the two drums, and the other is not, so that the motion of the two dead pullies on which these straps act are always in contrary directions to each other, whilst the axis on which they run is stationary. The two straps are guided by passing through eyes attached to a side rail of a square frame, which includes the axis with both its riggers and great wheel, and is suspended from the top of the machine by four pendulous rods, so that it has free motion to swing backwards and forwards in a direction parallel to the length of the axis of the pullies, which motion is communicated by a crank formed on a spindle, having a grooved wheel on the end of it. An endless rope passes over this wheel, and then descends to the bottom of the well, where it is strained beneath another wheel, so that the two sides of this rope are always in reach of the boy before-mentioned, who rides in a seat at the top of the cradle, giving him the means of turning the wheel and crank either way about, for by pulling down one of these guide ropes, he turns the wheel and crank, and draws the suspended frame one way, or by pulling down the other guide rope it is drawn the other. The consequence of these movements is, that the endless straps are shifted both together on one or other of their live pullies, whilst the other strap will be shifted upon the opposite dead pulley; consequently, the strap which is upon the live pulley turns the axis round one way or the other, drawing the cradle up or down, as it happens to be the crossed strap, or the opposite one, which is shifted on the live pulley, fixed on the axis at either side of the great wheel, which we first compared to a coach wheel. This is, in reality, a brake wheel, having a broad strap surrounding the lower half of it, both ends of which are conducted over two pullies, and levers with heavy weights draw down the ends, so that it has a constant tendency to press upwards beneath the wheel, to break, or cause such a friction upon it, as will stop its motion, when the two endless straps are shifted upon their dead pullies; but when the swinging frame is shifted either way, by the boy pulling down one of the guide ropes, which go down to the bottom of the well, and either of the straps are thus shifted upon the live pullies, the frame seizes the tail of a bent lever on each side the wheel, and relieves the weights which draw the strap against the wheel, and it hangs quite slack beneath the wheel, with a considerable space all round, so that its motion is quite free, and only under the influence of that strap which, being upon one of the live pullies, gives it motion in either direction. The crank before-mentioned for shifting the swinging frame is so contrived, that it always has a tendency, by means of a weight, to assume such a position, that it will direct the swinging frame, and the straps, both upon the dead pullies and the brake strap, being at the same time in contact with the lower half of the wheel, the cradle will

stand still; but when the crank, by pulling one of the guide ropes which go down to the bottom of the well, is turned to shift the endless straps either way, and consequently put the cradle in motion, the crank drops into a kind of hitch, or catch, which holds it in that position, but not so fast but that it can be relieved in a moment by snatching the guide or rope, and if left to itself it then assumes that position in which the crane will stand still. By this means the crane is in no danger of any accident, as it is always under the action of one or other of the endless straps, which cause it to ascend or descend, or it is under the brake strap, which makes it stand still, and the great advantage of all these movements are, that they act so softly, without any sudden jerks or snatches in changing from one state to another. The well has a gate fixed up at every floor to prevent people falling down into the mill, and if any person, on the fifth floor for instance, wishes to descend to the third, he goes to the gate and calls the boy, who, with the cradle, is perhaps below, to come to No. 5, which he does by snatching that guide rope which makes the crane draw up, when he sees the floor of the basket come exactly opposite the floor of the mill No. 5. He snatches the opposite rope; this jerks the crank out of its hitch, and it shifts the straps and brake, stopping the cradle in an instant, so that it is seldom half an inch out of level with the floor. The person who wishes to go down can now open the gate, which he could not do before, because the latch of the gate is lifted up by the cradle, when its floor is level with the floor of the gate, and stepping into the cradle he mentions the floor he wishes to go to, and the boy pulls down that directing rope which lets him down, and stops it at the floor he wishes, by snatching the other rope; but if he should pull the wrong, no harm can ensue, because the brake will always act to stop the machine, if the straps do not act to move it. The bobbins of the spinning frame, and the cops of the mule, are set up in little frames mounted on wheels, and thus wheeled along by little children to the crane, and drawn up or let down as required, without any hard labour; in fact the stairs are seldom used except for the people to go up and down when they begin and leave off work.

The stove which warms all the mill is situated down in the cave beneath the staircase: it is very ingeniously contrived with an iron cockle, or inverted cubical vessel, beneath which a fire is made, and the smoke escapes by a flue behind into a chimney. The air is then brought in a current to strike upon the external surface of this cockle, and being thus warmed, rises up through flues into every floor of the building, where it is admitted in any quantity at pleasure by registers, which are regulated to produce an agreeable warmth, but as the warm air escapes again with a draught through a proper ventilator, there is nothing of closeness connected with it.

Our limits will not permit us to describe more of the ingenious contrivances with which Messrs. Strutt's extensive mills at Belper abound, neither could the reader form a good idea of them without additional plates, and we have already exceeded our proposed number. Messrs. Strutt very liberally permitted the writer of this article to visit their works, for the purpose of composing it, to take drawings of the principal machines, which are of the very best construction of any in the cotton trade. These would have appeared here, but that the first six plates of our series were drawn and engraved some years ago, being intended for the article COTTON, at a time when the machinery was not brought to that perfection, in point of construction, that it is now. Indeed, the mechanical ingenuity called forth in

the whole manufacture of cotton, is beyond the conception of those who have not visited the countries where it is carried on. The tools and implements employed in constructing the different machines are very curious; for as there are such immense numbers of each part of every machine to be made, it becomes, in the same manner as with the clock-maker, worth the machine-maker's trouble to construct complicated tools and engines to expedite the manufacture of the parts; thus cutting engines for forming the teeth of the numerous wheels, see *Cutting ENGINE*. And here we would remark, that Mr. George Gilpin of Sheffield has, since the printing of that article, invented a method of cutting wheels from solid cast iron, with as much accuracy and as good a finish as brass wheels have hitherto been cut, making a very great saving in the expence of brass for a large mill, and much more durable when done. Card wires are manufactured in a very extensive scale in Yorkshire, and many very curious machines have been invented to diminish the labour of cutting and bending the wire teeth, and pricking the leathers for them: but a patent has been lately taken out, by Mr. J. C. Dyer, for a machine which cuts and bends the wires, pricks the leathers, and puts them in all at one operation, and with such rapidity, that it completes four *per* second. It is one of the most ingenious and perfect machines we ever met with, and it will prick and stick any sort or size of teeth, by altering adjustments introduced for that purpose. Drawings and a full description of this curious machine are lodged in the patent office by the patentee, who brought over the invention from America, where it has been some time in constant use. Curious lathes for turning spindles, and various other circular work, are used in the workshops of the cotton mills and sluting machines, for cutting the flutes in the lengths of the rollers of the drawing and spinning frames: in short, such works as Messrs. Strutt's at Belper, Mr. Arkwright at Crauford, in Derbyshire, Messrs. Phillips and Lees at Manchester, Mr. Peeles' and many others, are schools for mechanics in almost every department of the science; and good ones too, as the cotton manufacturers in general are convinced, that it is their interest to attend to every minutia in the construction of their machines, which may render them more durable or their operations more perfect. Among these improvements we may mention, what is becoming very general, *viz.* the addition of governors, or regulating balls, to the water-wheel, which turn the cotton mills, as they always keep it moving at the same speed, without which all the machines in the mill act irregularly, and it must happen that the velocity of the common water-wheel varies, when any number of machines are stopped, or cast in motion; but the regulated water-wheel always adapts its draught of water to the work it has to perform, preserving an uniform velocity in itself and all the machines it turns. This is brought to such perfection, that many such mills have a clock turned by the mill; close to it another clock, regulated in the usual manner by a pendulum, and the motion of the mill is so regular, that these two clocks will never vary more than two or three minutes. Both are made with dials and hands exactly alike, but one has a title on the dial, *mill* time, and the other, *clock* time. We shall take an opportunity of explaining a regulated water-wheel, under WATER-WHEEL.

We shall here close this article, though we have only gone through the detail of cotton-spinning, because the subsequent processes of weaving cotton-thread into cloth, dressing, finishing, printing, &c., have been or will be ex-

plained under the following several heads; viz. for explanations of the weaving processes, see *DRAUGHT of looms*, or *CORDING*, *DRAW-LOOM*, *DRAPER*, *DIMITY*, *DORNOCK*. Though the three last are rather linen than cotton, still the same processes apply in part to the weaving of cotton goods; see also *FUSTIAN*, and lastly, *WEAVING*. For the dressing of cloth after weaving, see *CALENDAR*, or rather *PRINTING of Calico*, which precedes the calendar, except for some particular goods; and as a part of calico-printing see *DIPPING*; also *BLEACHING*, *DYEING*, *DISCHARGING*, and *WASHING-WHEELS*. And, as we have before mentioned, a full account of the wonderful rise and progress of the cotton manufacture, which is wholly founded upon the improvements in the machinery for spinning, will be found under *COTTON*. Under the head of *SPINNING*, we shall describe those variations of the cotton machines, which

have been made to adapt them to the spinning of flax, wool, and worsted.

MANUFACTURERS. Persons enticing artificers into foreign countries incur the penalty of 500*l.* and twelve months imprisonment, for the first offence, for each person so seduced, and 1000*l.* and two years imprisonment, for the second offence. (23 Geo. II. c. 13.) And such artificers not returning within six months after warning, shall be deemed aliens, forfeit all their lands and goods, and be incapable of any legacy or gift. (5 Geo. I. c. 27.) By 22 Geo. III. c. 60. if any person shall contract with, or endeavour to persuade any artificer concerned in printing calicoes, cottons, muslins, or linens, or preparing any tools for such manufactory, to go out of the kingdom, he shall forfeit 500*l.* and be imprisoned for twelve months; for a second offence, 1000*l.* and be imprisoned for two years.

Marbles

MARBLES, Artificial. The stucco, whereof they make statues, busts, basso-relieues, and other ornaments of architecture, ought to be marble pulverised, mixed in a certain proportion with plaster; the whole well sifted, worked up with water, and used like common plaster. See STUCCO.

There is also a kind of artificial marble made of the flaky selenites, or a transparent stone, resembling plaster; which becomes very hard, receives a tolerable polish, and may deceive a good eye. This kind of selenites resembles Muscovy talc.

There is another sort of artificial marble, formed by corrosive tincture, which penetrating into white marble to the depth of a line or more, imitate the various colours of other dearer marbles.

There is also a preparation of brimstone in imitation of marble.

To do this, you must provide yourself with a flat and smooth piece of marble: on this make a border or wall, to encompass either a square or oval table, which may be done either with wax or clay. Then having provided several sorts of colours, as white-lead, vermilion, lake, orpiment, masticot, smalt, Prussian blue, &c. melt on a slow fire some brimstone, in several glazed pipkins; put one particular sort of colour into each, and stir it well together; then having before oiled the marble all over within the wall, with one colour quickly drop spots upon it of larger and less size; after this, take another colour and do as before; and so on, till the stone is covered with spots of all the colours you design to use. When this is done, you are next to consider what colour the mass or ground of your table is to be: if of a grey colour, then take fine sifted ashes, and mix it up with melted brimstone; or if red, with English red ochre; if white, with white-lead; if black, with lamp or ivory black. Your brimstone for the ground must be pretty hot, that the coloured drops on the stone may unite and incorporate with it. When the ground is poured even all over, you are next, if judged necessary, to put a thin wainscot board upon it: this must be done whilst the brimstone is hot, making also the board hot, which ought to be thoroughly dry, in order to cause the brimstone to stick the

better to it. When the whole is cold, take it up, and polish it with a cloth and oil, and it will look very beautiful. Smith's Laboratory, p. 248.

MARBLE, Colouring of. The colouring of marbles is a nice art, and in order to succeed in it, the pieces of marble, on which the experiments are tried, must be well polished, and clear from the least spot or vein. The harder the marble is, the better it will bear the heat necessary in the operation: therefore alabaster, and the common soft white marble, are very improper to perform these operations upon.

Heat is always necessary for the opening of the pores of the marble, so as to render it fit to receive the colours; but the marble must never be made red-hot, for then the texture of the marble itself is injured, and the colours are burnt, and lose their beauty. Too small a degree of heat is as bad as too great: for, in this case, though the marble receives the colour, it will not be fixed in it, nor strike deep enough. Some colours will strike, even cold; but they are never so well sunk in as when a just degree of heat is used. The proper degree is that which, without making the marble red, will make the liquor boil upon its surface. The menstrua used to strike in the colours must be varied according to the nature of the colour to be used. A lixivium made with horse's or dog's urine, with four parts quick-lime, and one part pot-ashes, is excellent for some colours; common ley of wood-ashes does very well for others; for some, spirit of wine is best; and finally, for others, oily liquors, or common white wine.

The colours which have been found to succeed best with the peculiar menstrua are these: stone-blue dissolved in six times the quantity of spirit of wine, or of the urinous lixivium; and that colour which the painters call litmus, dissolved in common ley of wood-ashes. An extract of saffron, and that colour made of buckthorn berries, and called by the painters sap-green, both succeed, well dissolved in urine and quick-lime, and tolerably well in spirit of wine. Vermilion, and a fine powder of cochineal, succeed also very well in the same liquors. Dragon's blood succeeds very well in spirit of wine, as does also a tincture of logwood in the same spirit. Alkanet-root gives a fine colour, but the only menstruum to be used for this is oil of turpentine; for

neither spirit of wine, nor any lixivium, will do with it. There is another kind of *sanguis draconis*, called dragon's blood in tears, which, mixed with urine alone, gives a very elegant colour. Phil. Transf. N° 268, or Abridg. vol. iv. part ii. p. 205.

Beside these mixtures of colours and menstrua, there are some colours which are to be laid on dry and unmixed. These are dragon's blood of the purest kind, for a red; gamboge for a yellow; green wax for a green; common brimstone, pitch, and turpentine, for a brown colour. The marble for these experiments must be made considerably hot, and then the colours are to be rubbed on dry in the lump. Some of these colours, when once given, remain immutable; others are easily changed or destroyed. Thus the red colour given by dragon's blood, or by a decoction of logwood, will be wholly taken away by oil of tartar, and the polish of the marble not hurt by it.

A fine gold colour is given in the following manner: take crude sal ammoniac, vitriol, and verdigris, of each equal quantities: white vitriol succeeds best, and all must be thoroughly mixed in fine powder.

The staining of marble to all the degrees of red, or yellow, by solutions of dragon's blood or gamboge, may be done by reducing these gums to powder, and grinding them with the spirit of wine, in a glass mortar; but for smaller attempts, no method is so good as the mixing of a little of either of these powders with spirit of wine, in a silver spoon, and holding it over burning charcoal. By this means a fine tincture will be extracted, and with a pencil dipped in this, the finest traces may be made on the marble, while cold, which, on the heating of it afterwards, either on sand, or in a baker's oven, will all sink very deep, and remain perfectly distinct in the stone. It is very easy to make the ground-colour of the marble red or yellow by this means, and leave white veins in it. This is to be done by covering the places where the whiteness is to remain with some white paint, or even with two or three doubles only of paper, either of which will prevent the colour from penetrating in that part. All the degrees of red are to be given to marble by means of this gum alone; a slight tincture of it, without the assistance of heat to the marble, gives only a pale flesh-colour; but the stronger tinctures give it yet deeper; to this the assistance of heat adds yet greatly; and finally, the addition of a little pitch to the tincture gives it a tendency to blackness, or any degree of deep red that is desired.

A blue colour may be given also to marble by dissolving turnsol in a lixivium of lime and urine, or in the volatile spirit of urine; but this has always a tendency to purple, whether made by the one or the other of these ways. A better blue, and used in an easier manner, is furnished by the Canary turnsol, a substance well known among the dyers. This needs only to be dissolved in water, and drawn on the place with a pencil: this penetrates very deep into the marble, and the colour may be increased by drawing the pencil, wetted afresh, several times over the same lines. This colour is subject to spread and diffuse itself irregularly; but it may be kept in regular bounds, by circumscribing its lines with beds of wax, or any other such substance. It is to be observed, that this colour should always be laid on cold, and no heat given even afterwards to the marble; and one great advantage of this colour is, that it is therefore easily added to marbles already stained with any other colours, and it is a very beautiful tinge, and lasts a long time. Mem. Acad. Par. 1732.

This art has in several people's hands been a very lucrative secret, though there is scarcely any thing in it that has not at one time or other been published.

Kircher has the honour of being one of the first who published any thing practicable about it. This author meeting with stones in some cabinets supposed to be natural, but having figures too nice and particular to be supposed to be nature's making, and these not only on the surface, but sunk through the whole body of the stones, was at the pains of finding out the artist who did the business; and on his refusing to part with the secret on any terms, this author, with Albert Gunter, a Saxon, endeavoured to find it out; in which they succeeded at length very well. Their method is this: take aqua fortis and aqua regia of each one ounce, sal-ammoniac one ounce, spirit of wine two drachms, about twenty-six grains of gold, and two drachms of pure silver; let the silver be calcined and put into a phial, and pour upon it the aqua fortis; let this stand some time, then evaporate it, and the remainder will first appear of a blue, and afterwards of a black colour; then put the gold into another phial, pour the aqua regia upon it, and when it is dissolved, evaporate it as the former; then put the spirit of wine upon the sal-ammoniac, and let it be evaporated in the same manner. All the remainders, and many others made in the same manner from other metals dissolved in their proper acid menstrua, are to be kept separate and used with a pencil on the marble. These will penetrate without the least assistance of heat, and the figure being traced with a pencil on the marble, the several parts are to be touched over with the proper colours, and this renewed daily till the colours have penetrated to the desired depth into the stone. After this the mass may be cut into thin plates, and every one of them will have the figure exactly represented on both surfaces, the colours never spreading. The nicest method of applying these, or the other tinging substances, to marble that is to be wrought into any ornamental works, and where the back is not exposed to view, is to apply the colours behind, and renew them so often till the figure is sufficiently seen through the surface on the front, though it does not quite extend to it. This is the method that of all others brings the stone to a nearer resemblance of natural veins of this kind. The same author gives another method to colour marble by vitriol, bitumen, &c. forming a design of what you like upon paper, and laying the said design between two pieces of polished marble; then closing all the interstices with wax, you bury them for a month or two in a damp place. On taking them up, you will find that the design you painted on the paper has penetrated the marbles, and formed exactly the same design on them. Kircher's Mund. Subter. lib. viii. § 1. cap. 9.

Wallerius, in his Mineralogy, vol. ii. p. 128. recommends the last method of Kircher; and the first method is copied in the Phil. Transf., N° 7.

The art was practised by Mr. Bird, a stone-cutter at Oxford, before the year 1666; but his method is not recorded. Mr. Robert Chambers, of Minching Hampton, in Gloucestershire, discovered and practised a method of colouring marble, which he kept a secret. Mr. Da Costa has published an account of experiments made on several pieces of marble stained by this artist. Phil. Transf. vol. li. art. 5. p. 30. &c.

Spots of oil stain white marble, so that they cannot be taken out. See STAINING of Stones.

MARBLE, Polishing of. The art of cutting and polishing marble was, of course, known to the ancients, whose mode of proceeding appears to have been nearly the same with that employed at present; except, perhaps, that they were unacquainted with those superior mechanical means which now greatly facilitate the labour, and diminish the expence of the articles thus produced. There are many celebrated manu-

factories of this kind generally called marble mills, on the continent, and also in Great Britain; but as the principle on which they proceed is nearly the same in all, it will suffice in this place to give the description of one or two of the latter. The following description, together with some preliminary observations, communicated by a person practically acquainted with this subject, relate to the manufactory of Messrs. Brown and Mawe at Derby.

An essential part of the art of polishing marble is the choice of substances by which the prominent parts are to be removed. The first substance should be the sharpest sand, so as to cut as fast as possible, and this is to be used till the surface becomes perfectly flat. After this the surface is rubbed with a finer sand, and frequently with a third. The next substance after the finest sand is emery of different degrees of fineness. This is followed by the red powder called tripoli, which owes its cutting quality to the oxyd of iron it contains. Common iron-stone powdered and levigated answers the purpose very well. This last substance gives a tolerably fine polish. This, however, is not deemed sufficient. The last polish is given with putty. After the first process, which merely takes away the inequalities of the surface, the sand employed for preparing it for the emery should be chosen of uniform quality. If it abounds with some particles harder than the rest, the surface will be liable to be scratched so deep as not to be removed by the emery. In order to get the sand of uniform quality, it should be levigated and washed. The hard particles, being generally of a different specific gravity to the rest, may by this means be separated. This method will be found much superior to that of sifting. The substance by which the sand is rubbed upon the marble is generally an iron plate, especially for the first process. A plate of an alloy of lead and tin is better for the succeeding processes, with the fine sand and emery. The rubbers used for the polishing, or last process, consists of coarse linen cloths, such as hop bagging, wedged tight into an iron plane. In all these processes, a constant supply of small quantities of water is absolutely necessary.

The sawing of marble is performed on the same principles as the first process of polishing. The saw is of soft iron, and is continually supplied with water and the sharpest sand. The sawing, as well as the polishing of small pieces, is performed by hand. The large articles, such as chimney-pieces and large slabs, are manufactured by means of machinery working by water or steam. We shall next give a description of this branch of manufacture in the large way, as carried on by Brown and Mawe at Derby, and in London, N^o 149 Strand, who have justly attained great celebrity as workers of spar and marble into different ornaments.

Fig. 1. Plate XXIII. Miscellany, is a side view of a mill for sawing and polishing slabs of marble; *fig. 2.* being a ground plan of the same, and marked with corresponding letters. *ABC* is a frame of wood, suspended by the upright frames of wood, *D, E, F, G*, from the beams *H, H, H, H*, so as to be capable of an oscillatory motion. Motion is given to this frame by the rod *I* communicating with the crank *O K*, which is turned by water or steam.

This frame, being put in motion, gives motion to the saw frames *L, L, M, M*, and to the polishing arms *N, P, Q*, which work on the pivot *P*, and are pushed backwards and forwards by the connecting iron rods *n, n*. The saws are iron plates shaped like a common saw, and fastened into oblong rings by means of pins. These rings are put upon the cross bars *E, E, b, b*, and the saws are stretched tight by the screws *s, s, s*, and *C*. *R, R, S, S*, are four upright posts

constituting a frame, in which are placed the blocks of marble to be sawn into slabs, which are at the same time to guide the frame of the saw. At each end of this frame there are a number of upright square bars of iron *i, i*, between which the saws pass which bars, act as conductors. The posts *R, R*, can be removed to a greater distance, so as to make the frame longer for receiving different sized blocks. The part *T*, to which the saw is attached on the moveable frame, slides upon the upright post *A C*. It is suspended by a rope, which goes over a pulley *c*, and is counterbalanced by the weight *W*. By this means the saw may be made to press upon its work with any degree of force. It will be evident that the moveable frame, from its pendulous motion, does not move in a straight line, but a curve. The sliding part *T*, therefore, serves to induce a rectilinear motion of the saw. The upright bars of iron *i, i*, and *C*, are of a size equal to or less than the thinnest slabs, so that the saws may be placed at different distances, according to the thickness of the slabs. In order to alter the saws for this purpose, nothing more is necessary than to loosen the screws *s, s*, &c. and shift the oblong rings which contain the saws.

The slabs of marble to be polished are laid upon the carriage *b*, so as to correspond with the rubber *Q*, which passes over it in the direction of its length. In order to extend the rubber to the other parts of the slab, the carriage, *b*, has a lateral motion, by means of four grooved wheels running upon the iron guiders let into the beams *g, g*. The endless screw *c*, in the main shaft, turns the wheel *r*. This gives motion to the lever *ev. fig. 2*, by means of the crank *g*. The lever communicates with the crank *k*, and turns the wheel *l*, more or less of a revolution, according to the length of this crank, which can be altered at pleasure by shifting the temporary pin *e*. By this latter motion the wheel, *l*, works the ratch *v*, and gives the lateral motion to the carriage. By this means the whole of the surface is exposed to the action of the rubber. Round articles of spar, gypsum, and marble, are turned in the lathe with pointed instruments of hardened steel. The pieces to be turned are attached to a wooden chock by means of cement. The gypsum is very soft, and turns with great facility. The flint spar and marble require the tool to be very hard, while the part to be turned requires a constant supply of water, which drops from a vessel above. After the articles are turned into the given shape, they are dressed with sand and emery, and afterwards polished with tripoli and putty.

Small specimens for collections of marbles are generally polished upon a lap, which runs in a lathe. These laps, however, ought to run with the axis perpendicular to the horizon, the face of the lap being truly flat and horizontal. The lap used for the first process should be of iron; the second of an alloy of lead and tin; and the third, which is for polishing, should be of iron with pitch. By means of some auxiliary machinery, a number of pieces might be polished in this way at once, which would save much manual labour. Small pieces of marble may also be polished on the large machine, by cementing them with plaster on the surface of a large slab. By being placed on the same level, the large rubber sweeps them all at once.

The marble mill in the neighbourhood of Kilkenny, in Ireland, mentioned under the article *IRISH MARBLES, supra*, and which was invented by alderman Collis, grandfather of the present proprietor, is remarkable for the simplicity of its structure, and for the powers it exerts. One wheel, ten feet diameter, with twelve floats or ladles, gives motion, by a crank at one end of its axis, to a frame containing twelve saws, which do the work of about twenty men. By a

crank at the other end, it moves a frame of five polishers, which do the work of about ten men. At this end Mr. Collis has lately fitted a frame beneath the polishers, with eight saws, to the motion of which he has found the power of the machine fully equal. This mill may be fairly said to do the constant work of forty-two men daily. During the night the mill stopped, a constant attention being required to supply the saws with sand, and to attend the polishers. The saws are made of soft iron, and last about a week; they are constantly supplied with water and sand; the latter is taken out of the bed of the Nore, and washed till nothing remains, but very fine and pure siliceous particles. A saw cuts ten inches in a day, and twelve when the water is strong; it would require two men to do the same with a hand saw. The marble taken from the mill is first polished

with a *cove-stone*, that is, a brown sand-stone imported from Chester, and which takes its name from being used in chimney coves. It is afterwards polished by a *bone-stone*, which is a piece of smooth nodule of the argillaceous iron ore, found in the hills between Kilkenny and Freshford. It receives the last polish in the mill with rags and putty. By means of this mill, the marble is so easily worked as to be sold at a very moderate price.

A great improvement in cutting marble and other stones, but particularly columns by machinery, was invented in Ireland by the late sir George Wright, bart., who procured a patent for it. By this a number of hollow columns can be cut from a solid block, each decreasing in size, so that nothing of the stone is lost, except what is converted into dust by the saw.

Masonry

MASONRY is the art of preparing and combining stones, so as to tooth or indent them into each other, and form regular surfaces, either for shelter, convenience, or defence ; as the habitations of men, animals, the protection and shelter of goods, &c.

The tools employed by the mason are different in different countries, according to the quality of the stone.

In London, the value of stone occasions it to be cut into scantlings by a saw, and the operation is done by the labourer ; in different parts of the country where stone abounds, it is divided into smaller scantlings by means of wedges. Hard stone and marble are reduced to a surface by a mallet and chissel.

The principal implements used in London for hewing stones are the mallet and tools. The form of masons' tools, which are used by the percussive blows of the mallet, is that of a wedge ; the cutting edge is the vertical angle. The material out of which such tools are made is iron, except the end which enters the stone, which is of steel. The end of the tool which is struck by the mallet is a small portion of a spheric surface, and projects on all sides beyond the adjoining part or hand hold, which increases in magnitude towards the middle of the tool, and thence tapers forward, in the form of a wedge or pyramid, to the entering or cutting edge. The other tools used by the mason are, a level, a plumb rule, a square, a bevel, and rules both straight and circular, of various descriptions, for trying the surfaces in the progressive state of the work.

The tools used in London, in succession, to work the face of a stone, are, the point, the inch tool, the boaster, then the broad tool. The operation of working with the point is called *pointing*, and that with the boaster is called *boasting*. The operation of the point leaves the surface in narrow furrows, with rough ridges between them. The inch tool is used in cutting away the ridges, and the boaster in making the surface of the work nearly smooth. The point is in breadth, at the entering part, from $\frac{1}{4}$ th to $\frac{3}{4}$ ths of an inch, the boaster 2 inches wide, and the broad tool $3\frac{1}{2}$ inches at the cutting edge. In the use of the tool, the cutting edge is always perpendicular to the same side of the stone. There are two kinds of operations performed by it : suppose the impression made by the whole breadth of the tool, at the cutting edge, to be called a cavity. In one operation, the successive cavities follow one another in the same straight line, until the breadth or length of the stone is exhausted ; then successive equidistant parallel lines are repeated in the same manner,

until the whole surface of the stone has been gone over by the tool. This manner of hewing is called *stroking*, which is a kind of fluted surface. In the other operation, every successive cavity is repeated in new equidistant lines throughout the length or breadth of the stone, then a new series of cavities is again repeated throughout the length or breadth of the stone, and thus until the whole breadth or length of the stone is exhausted. This mode is called *tooling*.

Tools for working cylindrical and conical parts of mouldings are of all sizes, from $\frac{1}{4}$ th part of an inch upwards ; but those for working convex mouldings are generally half an inch broad, unless in confined spaces, where such breadth cannot be admitted.

A stone is taken, for the greater part, out of winding with points, and entirely with the inch tool.

In London, the facings of buildings made with squared stone, are either stroked, tooled, or rubbed.

In the country, where the saving of stone by the use of the saw is not a compensation for the loss of time taken up in sawing, the operation is entirely performed by the mallet and chissel.

When stones are very unshapely previous to the operation of hewing, a stone ax, jedding ax, scabbling hammer, or caviil, is used in order to bring the stone nearly to a shape : one end of the jedding ax is flat, and is used for knocking off the very protuberant angular parts when less than right angles, the other end is pointed for reducing the different surfaces nearly to the intended form.

In some parts of the country, different fancies of hewn surfaces are indulged, as herring-bone work : this is forming the surfaces of the stones by zig-zag lines parallel to each other.

In Scotland, besides what has already been noticed in hewn work, are other kinds denominated droved, broached, and striped. Droving is the same as that called random tooling in England, or boasting in London ; and the chissel for broaching is called a punch, and is the same as that called a point in England. Broached work is first droved and then broached, as the work cannot be done regularly at once with the punch. Striped work must also be first droved and then striped. Hence, of these three kinds of surfaces, the droved is the cheapest. Though broaching is sometimes performed without droving, it is never so regular ; and besides, the surface is generally full of inequalities. It must be observed, however, that workmen in general do not take the same pains to drove the face of a stone which is to be afterwards broached, as in that of which the droving is to remain the

final finish: these should be noticed by the superintendent. Drowing, broaching, and striping, are the terms used in Edinburgh and Glasgow, and in the south of Scotland. In Aberdeen, where the stone is very hard, being a kind of granite, the same operations cannot be employed. Instead of them they use a scabbling hammer, by which they pick the stone until the surface has nearly acquired its intended form. This manner of dressing the surface for the stone facing of a building is called *nidged work*, and the operation *nidging*. The term rubbed work is applied where the surface is smoothed by means of sand or grit stone.

Various curved rules, or templets and gauges, are also employed in hewn work. The tools used in setting or building are, a line and line pins, the level, the plumb rule, and rules of various descriptions, as also templets for circular work.

Marbles are polished by first being rubbed with grit-stone, then with pumice-stone, and lastly with emery or calcined tin.

The chief stone used in London is Portland, which comes from the island of Portland in Dorsetshire. It is used for public edifices, not only in ornaments, mouldings, and strings, but in all the exterior parts. In private buildings, where brick-work predominates, it is used in strings, window fills, balusters, steps, copings, &c. It must be observed, however, that under a great pressure it is apt to splinter or flush at the joints, and for this reason the joints cannot be made so close as many other kinds of stone will admit of. When it is recently quarried it is soft, and works easily, but acquires great hardness in length of time. The cathedral of St. Paul, Westminster bridge, and almost every public edifice in London, are constructed wholly, or in part, of Portland stone.

Purbeck stone comes from the island of Purbeck, in Dorsetshire also. It is mostly employed in rough work, as steps and paving.

Yorkshire stone is used where strength and durability are requisite, as in paving and coping.

Ryegate stone is used for hearths, slabs, and copings.

In Edinburgh a very fine stone called Craighleith, brought from a village of the same name in the neighbourhood of this city, is that most commonly used in the construction of their edifices. They have also very good stone from the Hails quarry, but rather inferior in point of colour.

This Craighleith quarry produces two kinds of rock, one of a fine cream or buff colour, called the liver rock, which is almost unchangeable, even though exposed in a building to the weather.

The city of Glasgow is built of various kinds of stone, the best of which are, the Possel and the Lord President's quarry: most other kinds are not only perishable, but liable to change their colour.

In the north of England, stone fit for hewn work is chiefly of a reddish colour. There is a very good white stone, however, in the vicinity of Liverpool, of which several of the public buildings are constructed.

All the stone fit to be squared, or squared and rubbed smooth, for the use of building, is mostly composed of sand. The stone used for the same purpose in the south of England is, in some parts, entirely chalk, and in other parts limestone. The Bath and Oxfordshire stone has so little grit in its texture, as to be wrought into mouldings with planes, as in joinery, and the surfaces are finished with an instrument called a *drag*.

Marbles, with regard to their contexture and variegation of colour, are almost of infinite variety: some are black, some white, some of a dove colour, and others beautifully variegated with every kind of rich colour. The best kind of white marble is that called *statuary*, and when cut into

thin slices becomes almost transparent, which property the others do not possess. The texture of marble, with regard to working, is not generally understood even by the best workmen, though upon sight they frequently know whether it will receive a polish or not. Some marbles are easily wrought, some are very hard, and other kinds resist the tools altogether.

Mortar is another principal material used in cementing the stones of a building. The reader who wishes to obtain a full knowledge in this department of masonry, may consult the article CEMENT, where he will receive satisfactory information.

Wherever it is intended to build upon, the ground must be tried with an iron crow or with a rammer: if found to shake it must be pierced with a borer, such as is used by well diggers; and if the ground proves to be generally firm, the loose or soft parts, if not very deep, must be excavated until a solid bed appears.

If the ground proves soft in several places to a great depth under apertures, and firm upon the site of the piers, turn inverted arches under the apertures, so that if the foundation sink, the arches will resist the re-action of the ground, then the whole wall will sink uniformly or descend in one body. Should the ground be even of an uniform texture, it is always eligible to turn inverted arches under apertures, wherever there is a part of a wall carried up from the foundation to the fill of that aperture: it is from neglecting this circumstance that the fills of windows in the ground stories of buildings are frequently broken; indeed it is seldom or never otherwise.

Arches adequate to this purpose should rather be of a parabolic form than circular, the figure of the parabola being better adapted to preserve an equilibrium than the arc of a circle, which is of uniform curvature. If unfortunately the soft parts of the ground prove to be the site of the piers, and, consequently, the hard places under the apertures, build piers under the apertures, and suspend arches between the piers with their concave side towards the trench as usual.

For more information upon this subject, the reader will refer to the article FOUNDATION.

In walling, the bedding joints have most commonly a horizontal position in the face of the work, and this disposition ought always to take place when the top of the wall terminates in an horizontal plane or line. In bridge building, and in the masonry of fence walls upon inclined surfaces, the bedding joints on the face sometimes follow the upper surface of the wall or terminating line.

The footings of stone walls ought to be constructed of large stones, which, if not naturally nearly square, should be reduced by the hammer to that form, and to an equal thickness in the same course; for if the beds of the stones in the foundation taper, the superstructure will be apt to give way, by resting upon mere angles or points with inclined beds instead of horizontal. All the vertical joints of any upper course should break joint, that is, they should fall upon the solid part of the stones in the lower course, and not upon the joints.

When the walls of the superstructure are thin, the stones which compose the foundation may be so disposed that their length may reach across each course, from one side of the wall to the other. In thicker walls, where the difficulty is greater in procuring stones of sufficient length to reach across the foundation, every second stone in the course may be a whole stone in the breadth, and each interval may consist of two stones of equal breadth, that is, placing header and stretcher alternately. But when those stones cannot be had

conveniently, from one side of the wall lay a header and stretcher alternately, and from the other side lay another series of stones in the same manner, so that the length of each header may be two-thirds, and the breadth of each stretcher one-third of the breadth of the wall, and so that the back of each header may come in contact with the back of an opposite stretcher, and the side of that header to come in contact with the side of the header adjoining the said stretcher. In broad foundations, where stones cannot be procured for a length equal to two-thirds of the breadth of the foundation, build the work so that the upright joints of any course may fall on the middle of the length of the stones in the course below, and so that the backs of each stone in any course may fall upon the solid of a stone or stones in the course below.

The foundation should consist of several courses, of which each superior course should be of less breadth than the inferior one, say four inches on each side in ordinary cases, and the upper course project four inches on each side of the wall. The number of courses must be regulated by the weight of the wall, and by the size of the stones of which the foundation consists.

A wall which is built of unhewn stone is called a *rubble* wall, whether with or without mortar. Rubble work is of two kinds, coursed and uncoursed. Coursed rubble is that of which the stones are gauged and dressed by the hammer, and thrown into different heaps, each heap containing stones of the same thickness; then the masonry is laid in courses or horizontal rows, which may be of different thicknesses. The uncoursed rubble is that where the stones are laid promiscuously in the wall, without any attention to placing them in rows. The only preparation which the stones undergo, is that of knocking off the sharp angles with the thick end of the scabbling hammer.

Walls are most commonly built with an ashler facing and backed with brick or rubble work. Brick backings are common in London where brick is cheaper, and stone backing in the north of England and in Scotland where stone is cheaper. Walls faced with ashler, and backed with brick or uncoursed rubble, are liable to become convex on the outside from the greater number of joints, and from the greater quantity of mortar placed in each joint, as the shrinking of the mortar will be in proportion to the quantity, and therefore a wall of this description is much inferior to one of which the facing and backing are of the same kind, and built with equal care, even though both sides were uncoursed rubble, which is the worst of all walling. Where the outside of a wall is an ashler facing and the inside coursed rubble, the courses of the backing should be as high as possible, and set with thin beds of mortar. In Scotland, where stone abounds, and where perhaps as good ashler facings are constructed as any in Great Britain, the backing of their walls most commonly consists of uncoursed rubble, built with very little care. In the north of England, where the ashler facings of walls are done with less neatness, they are much more particular in coursing of their backings. Coursed rubble and brick backings are favourable for the insertion of bond timbers: but in good masonry wooden bonds should never be in continued lengths, as in case of fire or rot the wood will perish, and the masonry, being reduced by the breadth of the timber, will be liable to bend at the place where it was inserted. When it is necessary to have wall timber for the fastening of battens for lath and plaster, the pieces of timber ought to be built with the fibres of the wood perpendicular to the surface of the wall, or otherwise in unconnected short pieces not exceeding nine inches in length.

In an ashler facing the stones generally run from twenty-eight to thirty inches in length, twelve inches in height, and eight or nine inches in thickness. Although both the upper and lower beds of an ashler, as well as the vertical joints, should be at right angles to the face of the stone, and the face bed and vertical joints at right angles to the beds in an ashler facing, where the stones run nearly of the same thickness, it is of some advantage, in respect of bond, that the back of the stone be inclined to the face, and that all the backs thus inclined should run in the same direction, as this gives a small degree of lap in the setting of the next course; whereas if the backs were parallel to the front, there could be no lap where the stones run of an equal depth in the thickness of the wall. It is of some advantage likewise to select the stones, so that a thicker one and a thinner one may follow each other alternately. The disposition of the stones in the next superior course, should follow the same order as in the inferior course, and every vertical joint should fall as nearly as possible in the middle of the stone below.

In every course of ashler facing, with brick or rubble backing, *through* stones (as they are technically termed) should be introduced, and their number should be proportioned to the length of the course, and every such stone of a superior course should fall in the middle of every two like stones in the course below: this disposition of bonds should be strictly attended to in all long courses. Some wallers, in order to shew or demonstrate that they have introduced sufficient bonds in their work, choose their bond stones of greater length than the thickness of the wall, and knock or cut off their ends afterwards. This method is far from being eligible, as the wall is not only liable to be shaken by the force applied to break the end of the stone, but the stone itself is apt to be split.

In every pier where the jambs are coursed with the ashler in front, every alternate jamb stone ought to go through the wall with its beds perfectly level. If the jamb stones are of one entire height, as is frequently the case when architraves are wrought upon them, and upon the lentil crowning them, in the stones at the ends of the courses of the pier which are to adjoin the architrave jamb, every alternate stone ought to be a through stone; and if the piers between the apertures be very narrow, no other bond stones will be necessary in such short courses. But where the piers are wide, the number of bond stones must be proportioned to the space: through stones must be particularly attended to in the long courses below and above windows.

Bond stones should have their sides parallel and of course perpendicular to each other, and their horizontal dimension in the face of the work should never be less than the vertical one. All the vertical joints, after receding about three quarters of an inch from the face with a close joint, should widen gradually to the back, and thereby form hollow wedge-like figures for the reception of mortar and packing. The adjoining stones should have their beds and vertical joints filled with oil putty from the face to about three quarters of an inch inwards, and the remaining part, of the beds with well prepared mortar. Putty cement will stand longer than most stones, and will even remain prominent, when the stone itself is in a state of dilapidation, by the influence of the corroding power of the atmosphere. It is true that in all newly built walls cemented with oil putty, the first appearance of the ashler work is rather unsightly, owing to the oil of the putty disseminating itself into the adjoining stones, which makes the joints appear dirty and irregular: but this disagreeable effect is removed in a year, or less; and if care has been taken to make the colour of the putty suitable to that of the stone, the joints will hardly

appear, and the whole work will seem as if one piece. This is the practice of Glasgow. In London and Edinburgh fine water putty is used instead of it.

All the stones of an ashler facing should be laid on their natural beds. From a neglect of this circumstance the stones frequently fluff at the joints, and this disposition of the lamina sooner admits the corroding power of the atmosphere to take place.

In building walls or insulated pillars of very small horizontal dimensions, every stone should have its beds level and without any concavity in the middle: because if the beds are concave, when the pillars begin to sustain the weight of the fabric the joints will in all probability fluff. It ought likewise to be observed that every course of masonry of such piers ought to consist of one stone.

Vitruvius has left us an account of the construction of the walls of the ancients, as follows. "The sorts of walls are the reticulated, *Plate I. fig. 1.*, and the ancient, which is called the incertain, *fig. 2.* Of these the reticulated is the handsomest, but the joints are so ordered that all the parts of the courses have an infirm position; whereas in the incertain, the materials rest firmly one upon the other, and are interwoven together; so that they are much stronger than the reticulated, though not so handsome. Both sorts are formed of very small pieces, that the walls, being saturated with mortar, may endure the longer: for the stones, being of a porous and spongy nature, absorb the moisture from the mortar; and when there is an abundance of mortar, the wall, having more humidity, will not so soon decay, but will on that account be rendered more durable; for as soon as the humidity is extracted from the mortar by the suction of the stones, then the lime and sand separating the cement is dissolved, and the mortar no longer uniting the materials, the walls soon become ruinous. This may be observed in some tombs near the city, which are built with marble or hewn stone, and the internal parts rammed with rubble stones; the mortar being by length of time drained of its humidity by the suction of the stones, and the union of the joints being dissolved, they separate and fall to ruin.

"To avoid this error, the middle space (*fig. 2.*) must be strengthened with abutments of the red hewn stone or bricks, or common flints, built in walls two feet thick, and bound to the front with cramps of iron fixed with lead; for the work being thus built in a regular manner, and not laid in promiscuous heaps, will remain without defect; and being by the orderly arrangement of the courses and joints firmly united and bound together, it will not be liable to fractures, nor will the abutments suffer it to fall to decay. For this reason the walls of the Greeks are not to be despised; for though they do not use smooth or polished materials, yet where they discontinue the square stones, they lay the flints, or common hard stones, that they use, in the same manner as bricks are generally laid, bending the courses together with alternate joints, and thus make their works strong and durable.

"These walls they build in two manners; one is called *Isodorum* (*fig. 3.*), and the other *Pseudisodorum* (*fig. 4.*) *Isodorum* is when all the courses are of an equal thickness; and *Pseudisodorum* when they are unequal. Both these sorts are firm; first, because the stones themselves are of a compact and solid nature, and do not absorb the moisture from the mortar, but preserve its humidity to a great age; and, secondly, being situated in regular and level courses, the mortar is prevented from falling, and the whole thickness of the wall being united, it endures perpetually.

"Another sort is that which they call *Emplecton*, *fig. 5*

and 6.) which is also used by our villagers. The faces of the stones in this kind are smooth; the rest is left as it grows in the quarry, being secured with alternate joints and mortar; but our artificers, quickly raising a shell, which serves for the faces of the wall, fill the middle with rubble and mortar: the walls, therefore, consist of three coats, two being the faces, and one the rubble core in the middle, *figs. 5 and 6.* But the Greeks do not build in that manner; they not only build the facing courses regularly, but also use alternate joints throughout the whole thickness, not ramming the middle with rubble, but building it the same as the face, and of one united coat construct the wall: besides this, they dispose single pieces (A), which they call *diatonos*, in the thickness of the wall, extending from one face to the other, which bind and exceedingly strengthen the walls. Those, therefore, who would build works of long duration, must attend to these rules, and make use of such methods of building; for the smooth polish, and beautiful appearance of the stones, will not prevent the wall from being ruined by age."

An arch, in masonry, is a part of a building suspended over a given plan, supported only at the extremities, and concave towards the plan.

The supports of an arch are called the *spring walls*.

The whole of the under surface of the arch opposite to the plan is called the *intrados* of the arch, and the upper surface is called the *extrados*.

The boundary line, or lines of the intrados, or those common to the supports and the intrados, are called the *springing lines* of the arch.

A line extending from any point in the springing line on one side of the arch, to the springing line on the opposite side of the arch, is called the *chord* or *span* of the arch.

If a vertical plane be supposed to be contained by the span and the intrados of the arch, it is called the section of the hollow of the arch.

The vertical line drawn on the section from the middle of the spanning line to the intrados, is called the *height* of the arch, as also the middle line of the arch, and the part of the arch at the upper extremity of this line is called the *crown* of the arch.

Each of the curved parts on the top of the section, between the crown and each extremity of the spanning line, is called the *haunches* or *flanks* of the arch.

The section of almost every given arch used in building has the following properties: the upper part is one continued curve, concave towards the span, or two curves forming an interior angle at the crown, both concave towards the spanning line.

Every two vertical lines on the section equidistant from each extremity, and parallel to the middle line, are equal.

The above definitions and propositions not only apply to arches with level bases, but also to arches which stand upon inclined bases.

When the base of the section or spanning line is parallel to the horizon, the section will consist of two equal and similar parts, so that if one were conceived to be folded upon the other, the boundaries of both would coincide.

Arches, the intrados of which is the surface of a geometrical solid that would fill the void, are variously named, according to the figure of the section of that solid perpendicular to the axis, as *circular*, *elliptical*, *cycloidal*, *catenarian*, *parabolical*, &c.

Arches of the circular kind have two distinctions, viz. the semicircle, and those of segments less than a semicircle, are called *fishbone* or *stone* arches.

There are also *pointed*, *composite*, *lancet*, or *Gothic* arches, which are formed in the face of the wall, or in sections parallel thereto, with the intrados of the arch.

When the extremities of an arch rise from supports at unequal heights, such an arch is called a *rampant* arch.

When a vertical line is drawn upwards, through each extremity of the spanning line, so as to cut off equal and similar parts of the intrados, the arch is called a *horse-shoe* arch, or *Morisque* arch. Hence, in this kind of arch, the spanning line is less than any other line or chord drawn parallel to the span, but under the top of each said vertical line.

When the upper line or side of an arch is parallel to the under line or side, the arch is called an *extradosed* arch.

A simple vault is an interior concavity extended over two parallel opposite walls, or over all the diametrically opposite parts of one circular wall. An arch or vault are frequently understood as synonymous; but the distinction which we shall here observe is, that an arch, though it may be extended over any space, has a very narrow intrados, not exceeding four or five feet; whereas a vault may be extended to any limit more than four or five feet. Thus, we frequently say an arch in a wall, but we never say a vault in a wall; though nothing is more common than to say a vaulted apartment, a vaulted room, a vaulted cellar, &c. So that a vault, as sir Henry Wotton has observed, is an extended arch; we shall therefore apply arch to the head of the aperture in a wall which shews curvilinear interfections with the faces of the wall, and the word vault to arched apartments. We frequently, however, call the stone-work suspended over an apartment an arch as well as a vault, so that every vault is an arch, but every arch is not a vault.

The intrados of a simple vault is generally formed of the portion of a cylinder, cylindroid, sphere, or spheroid, never greater than the half of the solid; and the springing lines which terminate the walls, or where the vault begins to rise, are generally straight lines parallel to the axis of the cylinder or cylindroid, or the circumference of a circle or ellipse.

A circular wall is generally terminated with a spherical vault, which is either hemispherical, or a portion of the sphere less than a hemisphere.

A vaulted apartment, surrounded by an elliptic wall, is generally covered with a spheroidal vault, which is either a hemispheroid, or a portion less than a hemispheroid.

A conic surface is seldom employed in vaulting; but when the vault is to have this kind of intrados, the intrados should be the half of a cone with its axis in a horizontal position, or a whole cone with its axis in a vertical position.

All vaults which have a horizontal straight axis are called straight vaults.

Besides what we have already denominated an arch, the concavities which two solids form at an angle are called an arch.

If one cylinder pierce another of a greater diameter, the arch is called a cylindro-cylindric arch; the cylindro being applied to the cylindric part which has the greater diameter, and the cylindric to that which has the less.

If a cylinder pierce a sphere of greater diameter than the cylinder, the arch is called a spherocylindric arch; and on the contrary, if a sphere pierce a cylinder of greater diameter than the sphere, the arch is denominated a cylindro-spheric arch.

If a cylinder pierce a cone so as to make a complete perforation through the cone, two complete arches will be formed, called cono-cylindric arches; and on the contrary, if a cone pierce a cylinder so as to make the interior concavity through the cylinder a complete conic surface, the arch is called a cylindro-conic arch.

If a straight wall be pierced with a cylindric aperture quite through, two arches will be formed, called plano-cylindric arches.

Every species of arches is thus denoted by two preceding words; the former ending in *o*, signifying the principal vault or surface cut through, and the latter in *ic*, signifying the kind of aperture which pierces the wall or vault.

When two cylindric vaults, or two cylindroidic vaults, or a cylindric and cylindroidic vault pierce each other, and also their axes, so that the diameter of each hollow may be the same when measured perpendicular to a plane passing through the axis of both surfaces, the figure so formed is called a groin: but for more particular information on this point, see the article GROWN.

The formation of stone arches, in various cases, has always been looked upon as a most curious and useful acquisition to the operative mason, or to the architect, or other person who is appointed to superintend the work. In order to remove the difficulties experienced in the construction of cylindric or cylindroidic arches, both in straight and circular walls, we shall here shew an example of each:

First, let it be required to construct a semi-cylindroidic arch cutting a straight wall with its axis oblique to the surface of the wall, but parallel to the horizon.

Let A B C D (*Plate II. fig. 1.*) be the plan of the aperture, A D and B C being the plan of the jambs; and A B and D C the plan of the sides of the wall: produce D A and C B to G and F: draw the straight line I G M F E at right angles with A G and C F: bisect G F at M: draw M H K, perpendicular to G F: make M H equal to the height of the intrados of the arch, and describe the semi-ellipse G H F, which is the section of the intrados of the arch: make G I, H K, and F E equal to the breadth of the beds of the arch stone, and describe the semi-ellipses I K E, which is the section of the extrados of the arch. Now suppose the distances between the joints around the intrados of the arch to be all equal, and all the joints to tend to the centre M; divide the semi-ellipse into such an odd number of equal parts, that each part may be in breadth equal to what is intended for the thickness of the stones at that part; produce E I to S, and extend the whole number of these parts from G to S; and through the points of division draw lines perpendicular to G S, or parallel to A G. Through all the points of division of the ellipse G H F, draw lines parallel to G A to meet A B; then take the lengths of all the parts of the lines so drawn that are terminated by G F and A B as follows: viz. make the first line on the left of G A equal to the first on the right of G A, and the point *b* will be obtained; and the second on the left of G A equal to the second on the right of G A, and the point *c* will be obtained; proceed in this manner until all the other points are obtained; then a curve being drawn through all the points A, *b*, *c*, *d*, &c. to T, will give the one edge of the envelope of the intrados of the arch; and by producing the perpendiculars erected upon G S to the points *e*, *f*, *g*, &c. and making the several distances *b e*, *c f*, *d g*, &c. equal to A D or B C, the points D, *e*, *f*, *g*, &c. to U, equal to the other edge of the envelope by tracing a curve through them; then A *b e d*, *b c f e*, *c d g f*, &c. are the soffits of the stones.

To find any bevel which the joints on the face of the arch makes with that on the intrados of the same. Let $p q$ be one of the joints tending to the centre M of the section of the arch: with the radius $M G$ describe an arc $G N O$, cutting $p q$ at N : draw $N P$ parallel to $G A$, cutting $A B$ at P : draw $P Q$ parallel to $F G$, cutting $G A$ at Q : draw $M L$ parallel to $G A$, cutting $A B$ at L , and join $L O$; then $Q L M$ is the bevel required: in the same manner may all the remaining bevels be found.

Again, let $p q r s$ be the section of an arch stone, then making two bevels, one to $q p s$ and the other to $r s p$, will be all the bevels that are necessary for that stone. Having obtained the several bevels, we shall now proceed to work the arch stone, whose section is $p q r s$: first work the lower bed of the stone corresponding to the joint $p q$, then draw a line for the soffit, which work also by means of the bevel $q p s$; then gauge the soffit to its breadth, and work the upper bed of the stone by means of the bevel $r s p$; then take the soffit mould from the envelope, and draw the ends of the stone which coincides with the faces of the wall; then with the face bevels $Q L M$, and $V L M$, work the face of the stone.

Note, that finding the bevels for half the arch will be sufficient by reverting them.

The other arch standing upon $D C$ shews the ends of the stones in the face of the wall; its boundaries are two ellipses of equal height to those of the section.

To construct a cylindro-cylindric arch, or a cylindric arch in a cylindric wall, the axis of the aperture being at right angles with the axis of the cylindric wall. Let $A B C D$ be the half plan of the wall, $B C$ being half of the convex curve, $A D$ half of the concave curve, $C D$ the middle line of the aperture tending to the centre of the concentric circles which form the plan, and $A B$ parallel to $C D$, being the jamb. Through C draw $E F$ perpendicular to $C D$: make $C E$ and $C F$ half the breadth of the aperture: from the centre C , with the radius $C E$ or $C F$, describe the semicircle $E G F$, which will be the section of the intrados: produce $C E$ and $C F$ to H and I , making $E H$ and $F I$ each equal to the breadth of the beds, and describe the semicircle $H K I$: divide the intradosal curve $E G F$ into

the number of parts answering to the number of arch stones, and proceed to find the envelope, as described, for the straight wall, which will give the moulds for the soffits of the stones as before.

To find the curves of the ends of the beds upon the face of the arch. Let $L M$ represent a joint: draw $L N$ and $M O$ perpendicular to $H I$, cutting the plan of the wall at N and O : draw $N P$ parallel to $C I$, cutting $M O$ at P : in $L M$ take any number of points t and y , and draw $t s$ and $y w$ parallel to $L N$, cutting the plan at s and w , and $N P$ at r and v : draw $M Q$, $t u$, $y x$, perpendicular to $L N$: make $M Q$, $t u$, $y x$, respectively equal to $P O$, $r s$, $v w$, and $L u x Q$ will be the curve of the joint required, which gives the face line of the upper bed of the lower stone, and the face line of the lower bed of the upper stone. In the same manner all the other face lines of the beds are to be found. The templet must be cut in the shape of $L M Q$.

To form an arch stone. First make one of the beds, then make the soffit, then form the other bed, then form the face lines of each bed, then run a draught round the three face lines, then between these work the face of the stone in lines perpendicular to the horizon. This will be easily found by drawing a vertical line upon the section of each stone.

It is only necessary to draw the moulds for one half of the arch, as the reverting of them in their application gives the stones of the other half.

The joints of any arch whatever may be found in the same manner, provided that the planes of the beds intersect a vertical plane perpendicular to the curve in the middle of the aperture.

It is obvious, on finding the face lines of the beds, that the lowest face line is the quickest, and part of the plan of the wall itself; the next face line is flatter, or has less curvature, and thus each successive face line has less curvature as it comes nearer to the top, and if there were a joint in the top, the face line of the beds would be quite a straight line. Indeed, the face lines of two or three courses might be wrought with straight edges, as the difference could hardly be perceived.

Fig. 2.
Incertain.

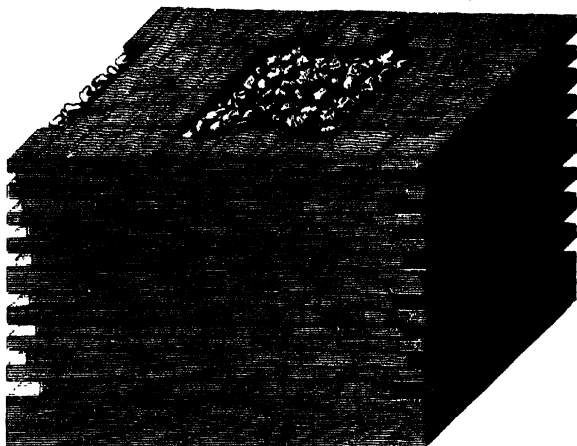


Fig. 1.
Reticulated.

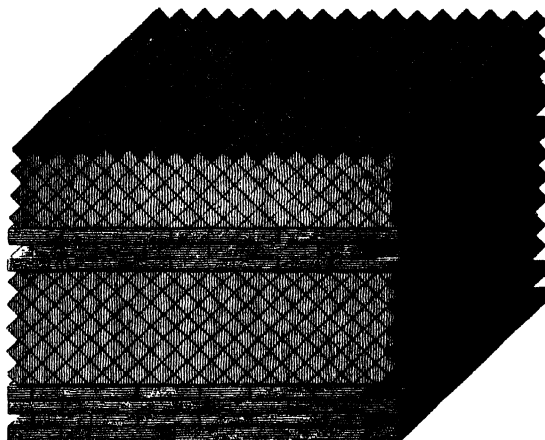


Fig. 4.
Pseudisodomum.

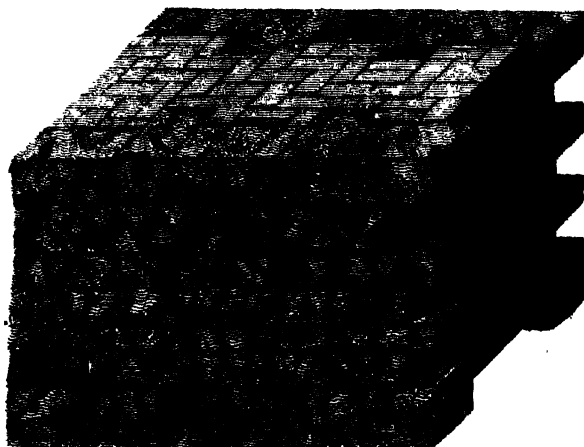


Fig. 3.
Isodomum.

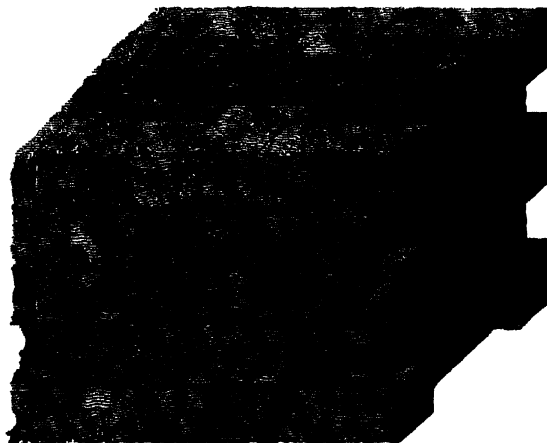


Fig. 6.
Greek Empletion.

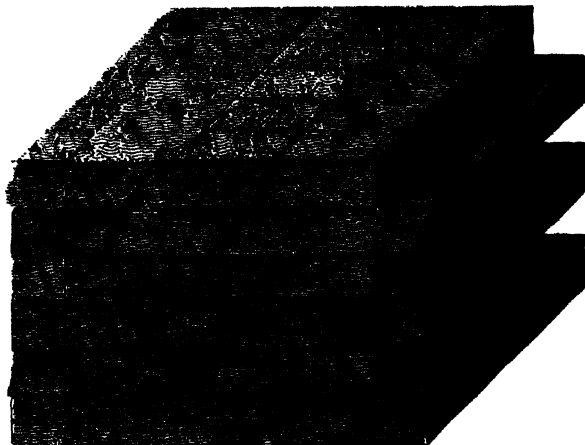
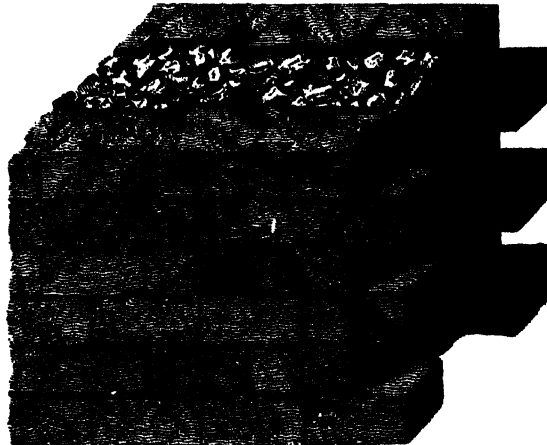


Fig. 5.
Roman Empletion.



MASONRY. ARCHES.

PLATE II.

PLANO-CYLINDROIDIC ARCH

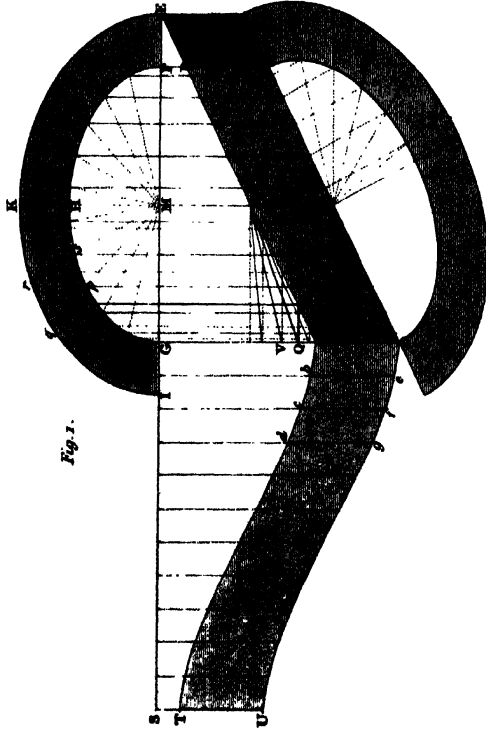


Fig. 1.

PLANO CYLINDRIC ARCH

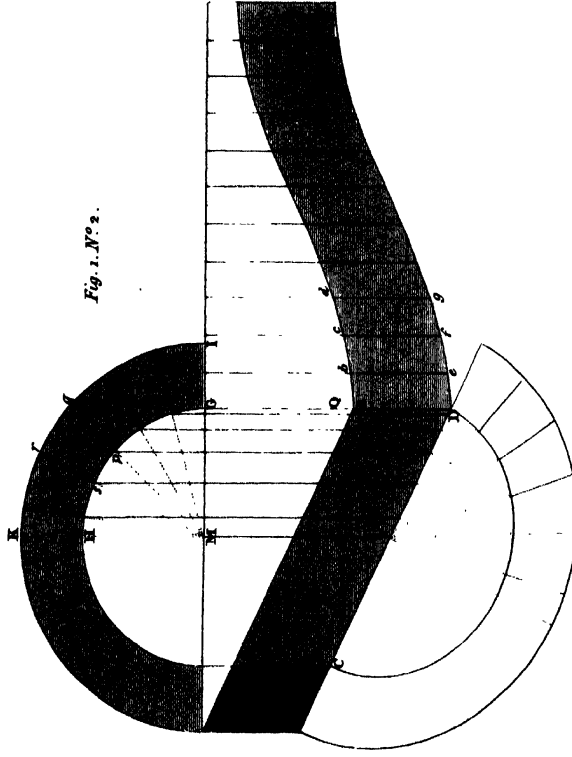


Fig. 1. N° 2.

CYLINDRO - CYLINDRIC

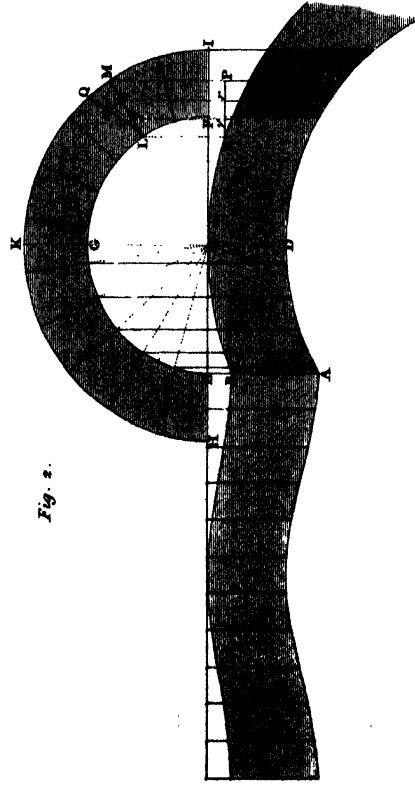


Fig. 2.

CYLINDRO - CYLINDROIDIC

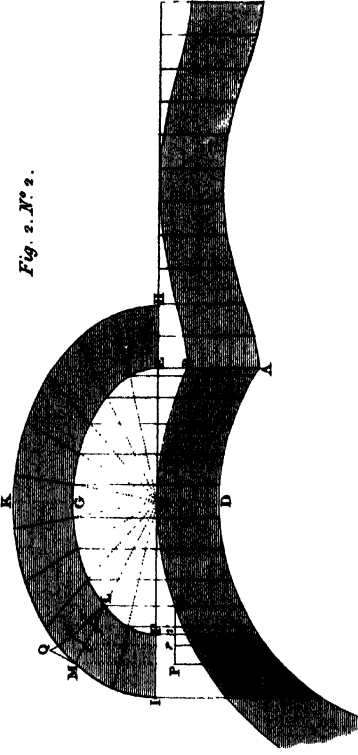


Fig. 2. N° 2.

Mechanics

MECHANICS, that branch of practical mathematics which considers motion and moving powers, their nature, laws, effects, &c. This term, in a popular sense, is applied equally to the doctrine of the equilibrium of powers, more properly called statics, and to that science which treats of the generation and communication of motion, which constitutes dynamics, or mechanics strictly so called. See **STATICS, POWER, MOTION, and DYNAMICS.**

This science is divided by Newton into practical and rational mechanics, the former of which relates to the mechanical powers, *viz.* the lever, balance, wheel and axis, pulley, wedge, screw, and inclined plane; and the latter, or rational mechanics, to the theory of motion; shewing, when the forces or powers are given, how to determine the motion that will result from them, and conversely when the circumstances of the motion are given, how to trace the forces or powers from which they arise.

Mechanics, according to the ancient sense of the word, considers only the energy of *organa*, or machines. The authors who have treated the subject of mechanics systematically have observed, that all machines derive their efficacy from a few simple forms and dispositions, that may be given to the *organa*, which are interposed between the agent and the resistance to be overcome; and to those simple forms they have given the name of mechanical powers, simple powers, or simple machines. See **MECHANICAL POWERS.**

The practical uses of the several mechanical powers were undoubtedly known to the ancients, but they were almost wholly unacquainted with the theoretical principles of this science till a very late period; and it is therefore not a little surprising that the construction of machines, or the instruments of mechanics, should have been pursued with such industry, and carried by them to such perfection. Vitruvius, in his 10th book, enumerates several ingenious machines which had then been in use from time immemorial. We find, that for raising or transporting heavy bodies, they employed most of the means which are at present commonly used for that purpose, such as the crane, the inclined plane, the pulley, &c.: but with the theory or true principles of equilibrium they seem to have been unacquainted till the time of Archimedes. This celebrated mathematician, in his book of Equiponderants, considers a balance supported on a fulcrum, and having a weight in each scale; and taking as a fundamental principle, that when the two arms of the balance are equal, the two weights supposed to be in equilibrio are also of necessity equal, he shews, that if one of the arms be increased, the weight applied to it must be proportionally diminished. Hence he deduces the general conclusion, that two weights suspended to the arms of a balance of unequal length, and remaining in equilibrio, must be reciprocally proportional to the arms of the balance; and this is the first trace any where to be met with of any theoretical investigation of mechanical science. Archimedes also farther observed, that the two weights exert the same pressure on the fulcrum of the balance, as if they were directly applied to it; and he afterwards extended the same idea to two other weights suspended from other points of the balance, then to two others, and so on, and hence, step by step, advanced towards the general idea of the centre of gravity, a point which he proved to belong to every assemblage of small bodies, and consequently to every large body, which might be considered as formed of such an assemblage. This theory he applied to particular cases, and determined the situation of the centre of gravity in the parallelogram, triangle, trapezium, parabola, parabolic trapezium, &c. &c. To him we are also indebted for the theory of the inclined plane, the pulley, and the screw, besides the invention of a multitude of compound machines, of which, however, he

has left us no description, and therefore little more than their names remain.

We may judge of the very imperfect state in which the theory of mechanics was at that time, by the astonishment expressed by king Hiero, when Archimedes exclaimed, "Give me a place to stand on and I will move the earth," a proposition which could have excited no surprise in any person possessing a knowledge of the simple property of the lever. Of the theory of motion, however, it does not appear that even Archimedes possessed any adequate idea; the properties of uniform motion seem only to have engaged the attention of the ancients, and with those of accelerated and variable motion they were totally unacquainted: these were subjects to which their geometry could not be applied, the modern analysis being necessary to bring this branch of the science to perfection.

From the time of Archimedes till the commencement of the sixteenth century, the theory of mechanics appears to have remained in the same state in which it was left by this prince of Grecian science, little or no additions having been made to it during so many ages; but about this time, Stevinus, a Flemish mathematician, made known directly, without the introduction of the lever, the laws of equilibrium of a body placed on an inclined plane: he also investigated, with the same success, many other questions on statics, and determined the conditions of equilibrium between several forces concurring in a common point, which comes, in fact, to the famous proposition relating to the parallelogram of forces; but it does not appear, however, that he was at all aware of its consequences and application. In 1592, Galileo composed a treatise on Statics, which he reduced to this single principle, *viz.* it requires an equal power to raise two different bodies to heights having the inverse ratio of their weights; that is, whatever power will raise a body of two pounds to the height of one foot, will raise a body of one pound to the height of two feet. On this simple principle he investigated the theory of the inclined plane, the screw, and all the mechanical powers, and Descartes afterwards employed it in considering the statical equilibriums of machines in general, but without quoting Galileo, to whom he had been indebted for the first idea. To Galileo we are also indebted for the theory of accelerated motion, and its complete coincidence with the observed phenomena of nature may be considered as one of the greatest steps made at one time in the science of physics. Since all bodies, said this philosopher, are heavy, into whatever number of parts we divide any mass, it follows, that its total weight is proportional to the number of material atoms of which it is composed. Now the weight being thus a power always uniform in quantity, and its action never undergoing any interruption, it must, in consequence, be continually giving new impulses to a body, in every equal and successive instant of time, and while the body is falling, these impulses are incessantly accumulating, and remain in the body without alteration, the resistance of the air alone being deducted, and hence the motion must be accelerated by equal degrees.

Torricelli, a pupil of Galileo, prosecuted the subject after his master, and added several curious propositions concerning projectiles, to those which the latter had previously investigated. Huygens considered the motion of bodies along given curves, and demonstrated that the velocity of a heavy body, which descends along any curve, is the same at every instant in the direction of the tangent, as it would have acquired by falling freely from a height equal to the corresponding vertical absciss. Then applying this principle to the inverted cycloid, the axis of which is vertical, he found

that a heavy body, from whatever part of the cycloidal arc it falls, always arrives at the lowest point of that arc in the same space of time. This very remarkable proposition includes what is commonly called the *isochronism* of the cycloid, and would alone have been sufficient to establish the fame of a geometrician. In 1661, Huygens, Wallis, and sir Christopher Wren, all discovered the true laws of percussion separately, and without any communication with each other, a proposition which Descartes had previously attempted, but failed in giving it a general solution. The finding of the centres of oscillation in compound bodies soon followed that relating to percussion, and here again Huygens equally distinguished himself by the accuracy and elegance of his solution; but as the principles which he employed were not well understood by the philosophers and mathematicians of that period, his investigations were much criticised at the time; but the honour of the discovery was finally attributed to him, and those of Descartes and Roberval admitted to be erroneous, or at least not sufficiently general. However, before the discovery of the fluxional calculus, there were many curious and interesting mechanical properties which the ancient geometry was incompetent to investigate, and which could never have been brought to light but by the assistance of this modern branch of analysis.

After the foundation of statics was laid by Archimedes, it was not difficult to discover the conditions of equilibrium in every particular case, and these had guided the genius of invention in a number of machines, but they were not yet reduced to a general and uniform principle.

Varignon undertook and accomplished this plan of combining them, by means of the theory of compound motions. He gave some sketches of this in 1687, in his *Project of a new System of Mechanics*, and he in some degree exhausted all the combinations of the equilibrium of machines, in his "*General Mechanics*," not published till after his death, in 1725. In 1695, la Hire published a "*Treatise on Mechanics*," the general object of which, like that of Varignon's, is the equilibrium of machines, beside which it contains various applications of machines to the arts, in which the author was well versed. He also subjoined a treatise on epicycloids, and their use in this science, particularly as relating to the forms of teeth in wheel-work. This is a beautiful theory, and is highly creditable to its author, who it appears from the testimony of Leibnitz was not la Hire, though he published it as such, but was due to the celebrated Danish mathematician Roemer, who had communicated it to Leibnitz twenty years before la Hire's work appeared. After this period, several elementary treatises on the subject of mechanics were published, without, however, adding much to the previous stock of knowledge, unless indeed we except that of Cornus, a work highly valuable for the strictness and perspicuity of its demonstrations.

At this time very little had been done with regard to the theory of variable motion; this now began to engage the attention of mathematicians, and opened an extensive field to their researches. Galileo, as we have seen, made known the properties of rectilinear and uniformly accelerated motions; Huygens had treated of curvilinear motion, which finally led to the beautiful theory of central forces in a circle, and which is equally applicable to motion in any curve, by considering them as infinite series of small arcs of a circle, agreeably to the idea which he himself had employed in his general theory of evolutes. The laws of the communication of motion, likewise sketched by Descartes, and farther pursued by Wallis, Huygens, and Wren, had made a new and very considerable step, by means of the solution which Huygens gave of the celebrated problem of the centres of oscillation,

All these acquisitions, at first separate and in some measure independent of each other, having been reduced to a small number of simple, commodious, and general formulæ, by means of the analysis of infinites, the science of mechanics acquired fresh vigour, and was prosecuted with the most unbounded success. The problems relating to motion were reduced into two classes; the first comprising the general problem of the motion of a single body acted upon by any given powers; and the second, the motions which result from the action and re-action that several bodies exert on each other in any given manner.

In the motion of a single body, we observe that matter, being of itself passive, if once set in motion, must uniformly persevere in it; and that its motion can neither increase nor diminish, unless by the action of some external power, which may be either constant or variable. And hence arise two principles, that of *vis inertia* and that of compound motion; and on these are founded the whole theory of motion, rectilinear or curvilinear, constant or variable, according to a given law. By virtue of the *vis inertia*, motion at every instant is essentially rectilinear and uniform, setting aside resistance and every obstacle that might otherwise impede or change its direction; and by the nature of compound motion, a body exposed to the action of a given number of forces, all tending at the same time to change the quantity and direction of its motion, takes such a path through space that in the last instant it reaches the same point at which it would have arrived, had it successively and freely obeyed each of the forces proposed.

On applying these principles to rectilinear motions uniformly accelerated, we perceive, 1st, that in this motion, the velocities increasing by equal degrees, or proportionally to the time, the accelerating force must be constant, or incessantly give equal impulses to the moving body, and that, consequently, the final velocity is as the product of the accelerating force multiplied by the time. 2dly. Each elementary portion of space passed through being as the product of the corresponding velocity multiplied by the element of the time, the whole of the space passed through is as the product of the accelerating force multiplied by the square of the time; and these two properties equally take place for each elementary portion of any variable motion whatever. Thus in every rectilinear motion variable according to a given law, the increment of the velocity is as the product of the accelerating force into the element of the time, and the second fluxion of the space passed through is as the product of the accelerating force into the square of the element of the time. Now if to these principles we add that of compound motion, we shall arrive at the knowledge of all curvilinear motion whatever. In fact, whatever forces be applied to a body describing a curve, we may at each instant reduce these forces to two, the one acting in the direction of the tangent at any point of the curve, and the other perpendicular to it; the first produces an instantaneous rectilinear motion, to which the principle of *vis inertia* applies; and the second is expressed by the square of the actual velocity of the body, divided by the radius of curvature, agreeably to the theory of central forces in the circle, which equally reduces to the same principle the motion in the direction of the radius of curvature. Such were the general principles introduced into the science of mechanics by means of the modern analysis, and there seems to be no doubt that it was by pursuing this theory, Newton was led to those brilliant discoveries which he afterwards published in his "*Principia*" under a different form. In 1716, Hermann published his "*De Phoronomia*," in which he undertook to explain all that regards mechanics, both of

solids and fluids, that is to say, statics, dynamics, hydrostatics, and hydraulics; in which he employs the synthetic method, although, like Newton, he doubtless derived most of his results from analysis, a circumstance which frequently interrupts the unity and connection of his problems.

The Mechanics of Euler, published in 1736, contain the whole theory of rectilinear and curvilinear motion in an isolated body, acted upon by any accelerating forces whatever, either in vacuo or in a resisting medium. The author has every where followed the analytical method, which, by reducing all the branches of this theory to uniformity, greatly facilitates the connection of it, and the whole is managed with an elegance and perspicuity, of which, before this time, we had no example. As to the principles of mechanics by which he puts his problems into equations, he employs those above mentioned.

This manner of laying the foundation of the calculation, however, though sufficiently commodious, was not the only one that might have been employed, nor was it the most simple. For the forces and motions at every instant may be resolved into other forces and motions parallel to fixed lines of given position in space. In which case nothing more is necessary than to apply the equations of the principles of *vis inertiae* to these motions and forces, by which means the theorem of Huygens may be avoided. This simple idea, which was first employed by Maclaurin in his "Treatise on Fluxions," threw new light on the theory of mechanics, and much facilitated the solution of various problems. When the body moves constantly in one plane, two fixed axes only are to be taken, which are supposed to be perpendicular to each other, for the sake of greater simplicity; but when we are obliged, by the nature of the forces, to change the path continually in all directions, and to describe a curve of double curvature, three axes are to be employed perpendicular to each other, or forming the edges of a right-angled parallelepipedon. But the problems relating to the communication of motion, commonly called *dynamic problems*, required new principles. These, for instance, consist in determining the motions that result from the percussion of several bodies; the centre of oscillation of a compound pendulum; the motions of several bodies strung upon a rod, which has a rotatory movement round a fixed axis; &c.

Now it is evident, that in all cases of this kind the motion of the bodies is not the same as if the bodies were isolated and at liberty, but that there must be a distribution of the forces among all the bodies forming one whole, so that the motion gained by some of them is lost by others. The motion gained or lost is always estimated by the product of the mass into the velocity received or lost, whether the communication or the loss of motion be produced every instant by finite degrees, as in the shock of hard bodies, or whether the velocity change at each instant only by degrees infinitely small, as in motion of several bodies strung on a moveable rod, and generally in all cases where forces act in the manner of gravitation.

When Huygens gave his solution of the problems of oscillation, some unskilful mathematicians attacked it in reviews. James Bernoulli defended it in the Leipzig Transactions for 1686, and undertook to give a direct demonstration by means of the principle of the lever. At first, he considered only two equal weights fastened to an inflexible rod devoid of gravity, which was in motion round an horizontal axis. Having then observed that the velocity of the weights, nearest to the axis of rotation, must necessarily be less, and that on the other greater, than if each acted on the rod separately, he concludes that the force lost and the force

gained balance each other, and that, consequently, the product of the quantity of matter in one, into the velocity it loses, and that of the other multiplied by the velocity it gains, must be inversely proportional to the arms of the lever. This reasoning is in fact accurate, only James Bernoulli mistook in setting out, by considering the velocities of the two bodies as finite, instead of which he should only have considered the elementary velocities, and compared them with the similar velocities produced every instant by the action of gravitation. De l'Hôpital remarked this error, and in correcting it, he found the centre of oscillation of the two weights, without departing in other respects from the principle of Bernoulli. In order then to proceed to a third weight, he united the former two at their centre of oscillation, and combined this new weight with the third, as he had combined together the former two, and so on. But the proposed union was a little precarious, and could not be admitted without a demonstration. This led Bernoulli to revive his former solution, in order to extend it generally to any number of bodies, which he finally accomplished. His method consists in resolving the motion of each body at any given instant into two other motions, the one, that which the body actually takes; and the other, that which is destroyed, and in forming equations which express the condition of equilibrium between the motions lost; by which means the problem is brought under the general laws of statics. The author applies this principle to several examples, and demonstrates strictly, and in the most evident manner, the proposition which Huygens employed as the basis of his solution. See Memoirs of the Academy of Sciences for 1703.

This solution of the problem of the centres of oscillation, seemed to leave nothing to be desired; yet, in 1714, it was brought forward again by John Bernoulli and Dr. Taylor, which were fundamentally the same. This occasioned warm disputes between them, as to the originality of their performances. Here, instead of the elementary weights of which the pendulum is composed, other weights are supposed to be substituted, in one and the same point, such that their motion of angular acceleration, and their motion with respect to the axis of rotation, shall be the same, and the new pendulum oscillate as the former. But these solutions are not considered so luminous as that of James Bernoulli, which was founded immediately on the laws of equilibrium. Leibnitz estimated the momenta of bodies by the mass into the square of their velocities, and John Bernoulli having adopted the same opinion, gave to the principles of Huygens, for the problem of the centres of oscillation, the name of the principle of conversion of the *vires vivæ*, which it has retained, because, in fact, in the motion of a system of heavy bodies, the sum of the products of the masses into the squares of the velocities remains the same, when the bodies descend conjointly, and when they afterwards ascend separately, with the velocities they acquired by their descent. This principle was also followed with success in dynamical problems, by several able analysts of the last century; but as it gives only a single equation, from which the velocity or the time must afterwards be expunged, the second object was attained by different means.

John Bernoulli employed for this purpose the principle of *tensions*; Euler, that of *pressures*; Daniel Bernoulli, that of *virtual power*, which a system of bodies has of re-establishing itself in its former state; and in certain cases both he and Euler made use of the constant quantity of circulatory motion round a fixed point. And when at length all the differential, or fluxional equations of the problem

were established, it remained only to resolve them, which was of course the least difficult part of their investigations.

The principle which had been employed by James Bernoulli, in the solution of the problem relating to the centre of oscillation, was generalized by D'Alembert; he shewed, that in whatever manner the bodies of one system act upon each other, their motions may always be resolved at every instant into two sorts of motions, those of the one being destroyed in the successive instant, but the other retained; and that the motions retained are necessarily known from the conditions of the equilibrium between the motions destroyed. This general principle applies to all the problems of dynamics, and at least reduces all their difficulties to those of the problems of simple statics; and renders useless that of the conversion of *vis viva*. By this means D'Alembert has resolved a number of very beautiful and very difficult problems, some of which were absolutely new, as, for example, that relating to the precession of the equinoxes. These general principles were first developed by D'Alembert in 1743, but they were more fully treated of in his Treatise of Dynamics, published in 1749; a truly interesting and original work, highly creditable to the talents of this celebrated author. The science of dynamics having thus gradually attained a high degree of perfection, was still farther enriched, in 1765, by an important discovery, which is due to Segner; who has shewn in a short paper entitled "*Specimen Theoriz Turbinum*," that if a body, of any size and figure, after rotatory or gyratory motions in all directions have been given to it, be left entirely to itself, it will always have three principal axes of rotation; that is, that all the rotatory motions, by which it is affected, may constantly be reduced to three, which are performed round three axes perpendicular to each other passing through the centre of gravity or inertiz of the body, and always preserving the same position in absolute space, while the centre of gravity is at rest, or moves uniformly in a right line; the position of these three axes being determined by an equation of the third order. This theory, which its author had not sufficiently developed, Albert, the son of the celebrated Euler, treated at length in his paper "On the Stowage of Ships," which shared the prize of the Academy of Sciences at Paris for 1761, as did likewise his father, according to the same method, in the Memoirs of the Academy at Berlin for 1759, and in his work entitled "*Theoria Motus Corporum rigidorum*, 1765." Lastly, D'Alembert shewed in his "*Mathematica Opuscula*," vol. iv. published in 1768, that the solution of the problem was deducible from the formulæ which he had given in a memoir for determining the motion of a body of any figure, acted upon by any forces whatever, printed in vol. i. of his *Opuscula* in 1761. The knowledge of these motions of free rotation round three principal axes, naturally led to the determination of the motion round any variable axes whatever; and hence, if we consider the body to be acted upon by any given accelerating forces, we must begin with determining the rectilinear or curvilinear motion of the centre of gravity abstractedly from all rotatory motion, and then combining this progressive motion with the rotatory motion of a given point of the body round a variable axis, we shall know at every instant the compound motion of this point in absolute space. On these principles Euler has resolved many curious and interesting problems relating to dynamics, and the same have been since farther proved by subsequent mathematicians. (Bossut's *Hist. Math.*) We have thus given a sketch of the history and successive improvements of the science of mechanics, which is all that is necessary under the present

article, as the particular branches connected with this subject are treated of separately under their respective heads in the different articles of this work. But as we have only directed our attention to the more prominent parts of the history, the works to which our references have been made are very limited. It remains, therefore, before we conclude this article, to enumerate some of the principal writers on mechanics, or on particular branches of it, which are as follows, *viz.*

Newton, in his "*Principia*;" Guido Ubaldo, in his "*Liber Mechanicorum*;" Torricelli, "*Libri de Motu Gravium naturalis Decendentium et Projectorum*;" Balianus, "*Traçtatus de Motu naturali Gravium*;" Huygens, "*Horologium Oscillatorium*," and "*Traçtatus de Motu Corporum ex Percussione*;" Leibnitz, "*Resistentia Solidorum*," in *Acta Euroditus*, ann. 1684; Guldinus, "*De Centro Gravitatis*;" Wallis, "*Traçtatus de Mechanica*;" Varignon, "*Projet d'une Nouvelle Mechanique*," and his papers in the *Memoires Acad.* ann. 1702; Borelli, "*Traçtatus de Vi Percussionis, de Motionibus naturalibus, &c.*;" De Chales, "*Treatise on Motion*;" Pardies, "*Discourse on Local Motion*;" Parent, "*Elements of Mechanics and Physics*;" Catatus, "*Mechanica*;" Oughtred, "*Mechanical Institution*;" Robault, "*Traçtatus de Mechanica*;" Lamy, "*Mechanique*;" Keil, "*Introduction to true Philosophy*;" De la Hire, "*Mechanique*;" Mariotte, "*Traçti du Choc du Corps*;" Ditton, "*Laws of Motion*;" Hermann, "*Phoronomia*;" Gravesande, "*Physics*;" Euler, "*Traçtatus de Motu*;" Muschenbroeck, "*Physics*;" Bossu, "*Mechaniques*;" La Grange, "*Mechanique Analytique*;" Atwood, "*On Motion*;" Prony, "*Architcture Hydraulique*," and "*Mechanique Analytique*;" Francear, "*Mechanique*;" Gregory, "*Mechanics in Theory and Practice*," &c. &c. to which may be added the names of Nicholson, Enfield, Wood, Ferguson, Young, and Marat. For those works which relate principally to the description of machinery, see the article MACHINE.

MECHANICAL, something that relates to mechanics, or is regulated by the nature and laws of motion.

In which sense we say mechanical powers, mechanical properties or affections, mechanical principles, reasoning, knowledge, &c.

MECHANICAL Affections, are such properties in matter, as result from their figure, bulk, and motion.

MECHANICAL Causes, are those founded on such affections.

MECHANICAL Force. See FORCE.

MECHANICAL Solutions, are accounts of things on the same principles.

MECHANICAL Philosophy, is the same with what we otherwise call the *corpuscular philosophy*; *viz.* that which explains the phenomenon of nature, and the operations of corporeal things, on the principles of mechanics; *viz.* the motion, gravity, figure, arrangement, disposition, greatness, or smallness of the parts which compose natural bodies. See CORPUSCULAR.

MECHANICAL Powers, (so called,) are those machines which are used for raising greater weights, or overcoming greater resistances than could be effected by the natural strength without them; the power of strength being applied to one part of the machine, and another part of the machine applied to the weight or resistance.

There are two principal problems that ought to be resolved in treating of each of them.

The first is, to determine the proportion which the power

and weight ought to have to each other, that they may just sustain one another, or be in equilibrio.

The second is, to determine what ought to be the proportion of the power and weight to each other in a given machine, that it may produce the greatest effect possible, in a given time.

As to the first problem, this general rule holds in all powers; suppose the engine to move, and reduce the velocities of the power and weight to the respective directions in which they act; find the proportions of those velocities; then if the power be to the weight as the velocity of the weight is to the velocity of the power; or, which amounts to the same thing, if the power multiplied by its velocity, gives the same product as the weight multiplied by its velocity, this is the case wherein the power and weight sustain each other, and are in equilibrio; so that in this case the one would not prevail over the other, if the engine was at rest; and if it is in motion, it would continue to proceed uniformly, if it were not for the friction of its parts, and other resistances.

The second general problem in mechanics is, to determine the proportion which the power and weight ought to bear to each other, that when the power prevails, and the machine is in motion, the greatest effect possible may be produced by it in a given time. It is manifest, that this is an enquiry of the greatest importance, though few have treated of it. When the power is only a little greater than that which is sufficient to sustain the weight, the motion is too slow; and though a greater weight is raised in this case it is not sufficient to compensate the loss of time. When the weight is much less than that which the power is able to sustain, it is raised in less time; and this may happen not to be sufficient to compensate the loss arising from the smallness of the load. It ought, therefore, to be determined when the product of the weight, multiplied by its velocity, is the greatest possible; for this product measures the effect of the engine in a given time, which is always the greater in proportion as the weight which is raised is greater, and as the velocity with which it is raised is greater. For other considerations necessary to be regarded in the construction and use of machines, we refer to the articles MACHINE and MACHINERY.

The simple machines by which power is gained, are six in number, viz. the *lever*, the *wheel and axle*, or *axis in peritrochio*, the *pulley* (or rather system of pulleys), the *inclined plane*, the *wedge*, and the *screw*. Of these, all sorts of mechanical engines consist; and in treating of them, so as to settle their theory, we must consider them as mechanically exact, and moving without friction. Although these machines are treated of at large under their proper heads, it may not be amiss to give a short account of them all here.

1. A *lever* is an inflexible bar, turning upon a supporting prop as its centre of motion, which must be firm enough to bear the lever and the weight with which it is charged. There are three kinds of levers, and in each of them the velocity of each point is directly as its distance from the prop.

A lever is said to be of the first kind when the prop is between the weight and the power. Here the power and weight balance each other, when the power is in proportion to the weight as the distance of the weight from the prop is to the distance of the power from it; so that if a weight be twenty pounds, and at one foot from the prop, a power of one pound at twenty feet from the prop will balance the weight, supposing the lever itself to have no weight. To this sort of lever may be reduced all iron crows, scissars, pinchers, candle-snuffers, and the like.

A lever is said to be of the second kind, when the weight is between the prop and the power. Here the lever and weight balance each other when the power is in proportion to the weight as the distance of the weight from the prop is to the distance of the power from it. Of this sort are doors turning on hinges, oars, and such knives as are fixed at the point.

A lever is said to be of the third kind when the power is between the weight and the prop. In this, the power and weight balance each other, when the power is in proportion to the weight, as the distance of the weight from the prop is to the distance of the power from it: but this lever is never used where power is wanted to be gained; for in it, the intensity of the power applied, must always exceed the intensity of the weight to be raised, or resistance to be overcome. Of this sort are the bones of our legs and arms, and the wheels of clocks and watches. See LEVER and BALANCE.

2. In the *wheel and axle*, where the power is applied to the wheel, and the weight drawn up by a rope winding round the axle, the velocity of the power is to the velocity of the weight, as the circumference of the wheel is to the circumference of the axle, and the advantage gained by the machine is in the same proportion: for the power and weight balance each other when the power is in proportion to the weight, as the circumference of the axle is to the circumference of the wheel. This machine is the principal part of a common crane. See AXIS in *Peritrochio*.

3. A *pulley*, that only turns on its axis, and does not rise with the weight, serves only to change the direction of the power; for it gives no mechanical advantage thereto. But when, besides the upper pulleys, which turn round in a fixed frame, or block, there is a block of pulleys moving equally fast with the weight, the velocity of the weight is to the velocity of the power as one is to twice the number of pulleys in the moveable block: and the power and weight balance each other when the power is in proportion to the weight, as one is to twice the number of pulleys in the moveable block. See PULLEY.

4. An *inclined plane* is like one-half of a wedge which has been cut in two equal parts lengthwise. A weight raised, or a resistance moved, by an inclined plane, moves only through a space equal to the height of that machine, in the time that a power drives it through a space equal to its whole length. Therefore, the velocity of the power is in proportion to the velocity of the weight, as the length of the machine is to its thickness or height at the back; and the power and weight balance each other when the power is in proportion to the weight, as the thickness of the plane is to its length. All edge tools, which are chamfered (or ground down only on one side to the edge) are inclined planes, as far as the chamfer goes from the edge. See INCLINED PLANE.

5. A *wedge*, in the common form, is like two inclined planes, joined together at their bases; and the thickness of these planes (opposite their sharp edges) makes the back of the wedge, to which the power of the sledge or hammer is applied in cleaving of wood.

When two equal resistances act perpendicularly against opposite sides of the wedge, and a power acts perpendicularly against the back of the wedge, the velocity of the power is in proportion to the velocity of the resistance on either side, as the length of the side is to half the thickness of the back; and the power balances the resistance of the wood, when the power is in proportion to the resistance, as half the thickness of the back of the wedge is to the length of either of its sides, if the sharp edge goes to the bottom

of the cleft in the wood. But when the wood splits before the wedge, as it generally does, the power balances the resistance, when the former is to the latter as half the thickness of the wedge (when it is driven quite into the wood) is to the whole length of the cleft below the back of the wedge. See WEDGE.

6. The *screw* may be considered as if it were an inclined plane, wrapped round a cylinder. In this machine, the power must turn the cylinder quite round, in the time that the weight or resistance (as in a common press) moves through a space equal to the distance between the threads or spirals of the screw. Therefore, the velocity of the power is in proportion to the velocity of the weight or resistance, as the circumference of a circle, described by the power, is to the distance between the spirals of the screw; and the power and resistance balance each other, when the former is to the latter as the distance between the spirals is to the circumference of the circle described by the power. This machine, besides the advantage peculiar to itself, has generally the benefit of the wheel and axle, on account of the winch or lever by which it is turned. See SCREW.

Of these six simple machines, all the most compound engines in the world are made. As the screw includes the inclined plane, and two equally inclined planes make the wedge, we have all the mechanical powers combined together in a common jack, if it be turned by the fly; for then we have also the lever, the wheel and axle, and the pulleys.

Thus, in a frame *ABCD*, (*Plate XXXII. Mechanics, fig. 5.*) fastened by the nut *O* upon the stand *OO*, and held together by the pillars *VW* and *Bq*, is adapted first the piece *EF*, whose fans or flies may be put in motion by the wind, or drawn by a hair fastened at *F*, which represents the lever and balance: at right angles to this piece is joined the perpendicular spindle *GH*, having upon it the endless screw *H*, which may be also considered as a wedge. This endless screw or worm takes the skew teeth of the wheel *K*, which is the axis in peritrochio, and, in turning round, winds up the string *LM* upon its axis, which passing round the pulleys at *M* and *N*, or drawing by a tackle of five, raises the weight *P*. But as the screw has no progressive motion on its axis, it cannot here be said to comprehend the inclined plane; therefore, in order to make this machine take in all the mechanical powers, we may add the inclined plane, *rqQR*, by making it rest on the ground at *QR*, and on the pillar *qB*, at *qr*, and thereby the force of the power drawing at *F*, will be farther increased in the proportion of *QT* to *TS*. The whole force gained by this machine is found by comparing the space gone through by the point *F*, with the height through which the weight is raised, in any determinate number of revolutions of *F*. An hundred pounds weight at *P* will be easily raised by the hair of a man's head drawing at *F*.

If an engine constructed in this manner be used for raising a weight, by means of a power applied to the fly, the power will balance the weight, if it be in proportion to the weight as the velocity of the weight is to the velocity of the fly. Now, considering how fast the fly moves with respect to the motion of the weight, it is evident, that a crane, constructed in the manner of a common jack, would be an engine of very great power. But then the time lost in raising the weight would also be very great: for, in any machine or engine whatever, the time lost in working it will be as great as the power gained by it.

If machines or engines could be made without friction, the least degree of power added to that which balances the weight would be sufficient to raise it. In the lever, the friction is next to nothing; in the wheel and axle it is but

small; in the pulleys it is very considerable; and in the inclined plane, wedge, and screw, it is very great. The universal law or principle in all mechanical machines or engines, made to gain power, is, that the power gained will be always as great as the velocity of the power exceeds the velocity of the weight or resistance: and, upon this principle, it is easy to compute the power, force, or advantage, of any simple machine or compound engine whatever.

E gr. If the body *A* (*Plate XXXII. Mechanics, fig. 6.*) be triple the body *B*, and each of them be so fixed to the extremities of a lever *AB*, whose fulcrum or fixed point is *C*, as that the distance of *BC* be triple the distance *CA*; the lever cannot be inclined on either side, but the space *BE*, passed over by the less body, will be triple the space *AD*, passed over by the great one. So that their motions or moments will be equal, and the two bodies in equilibrio.

Hence that noble challenge of Archimedes, *datis viribus, datum pondus movere*; for as the distance *CB* may be increased infinitely, the power or moment of *A* may be increased infinitely. So that the whole of mechanics is reduced to the following problem.

Any body, as A, with its velocity C, and also any other body, as B, being given; to find the velocity necessary to make the moment or quantity of motion, in B, equal to the moment of A, the given body. Here, since the moment of any body is equal to the rectangle under the velocity, and the quantity of matter; as *B : A :: C : to a fourth term*, which will be *c*, the celerity proper to *B*, to make its moment equal to that of *A*. Wherefore in any machine or engine, if the velocity of the power be made to the velocity of the weight, reciprocally as the weight is to the power, such power will always sustain, or, if the power be a little increased, it will move the weight.

Let, for instance, *AB* be a lever, whose fulcrum is at *C*, and let it be moved into the position *aCb*. Here, the velocity of any point in the lever is as the distance from the centre. For let the point *A* describe the arc *Aa*, and the point *B* the arc *Bb*; then these arcs will be the spaces described by the two motions: but since the motions are both made in the same time, the spaces will be as the velocities. But it is plain, the arcs *Aa* and *Bb* will be to one another as the radii *AC* and *CB*, because the sectors *ACA* and *BCb* are similar: wherefore the velocities of the points *A* and *B* are as their distances from the centre *C*.

Now if any powers be applied to the ends of the lever *A* and *B*, in order to raise its arms up and down; their force will be expounded by the perpendiculars *Sa* and *bN*; which, being as the right sines of the former arcs, *aA* and *bB*, will be to one another also as the radii *AC* and *CB*; wherefore the velocities of the powers are also as their distances from the centre. And since the moment of any body is as its weight, or gravitating force, and its velocity, conjunctly; if different powers or weights be applied to the lever, their moments will always be as the weights and the distances from the centre conjunctly. Wherefore, if to the same lever there be two powers or weights applied reciprocally proportional to their distances from the centre, their moments will be equal; and if they act contrarily, as in the case of a steel-yard, the lever will remain in an horizontal position, or the balance will be in equilibrio. And thus it is easy to conceive how the weight of one pound may be made to equilibrate a thousand, &c.

Hence also it is plain, that the force of the power is not at all increased by engines; only the velocity of the weight, in either lifting or drawing, is so diminished by the application of the instrument, as that the moment of the weight is not greater than the force of the power. Thus, for instance,

if any force can raise a pound weight with a given velocity, it is impossible by any engine to effect, that the same power shall raise two pound weight with the same velocity: but by an engine it may be made to raise two pound weight, with half the velocity: or 1000 times the weight with $\frac{1}{1000}$ of the former velocity.

We shall here introduce into one view, an account of the principal methods that have occurred to us of explaining and demonstrating the fundamental property of the several mechanical powers. It has been already observed, that, with regard to the lever, when any two forces act against each other on its arms, they will continue in equilibrio, if their quantities are inversely as the distance between the points to which they are applied, and the point or fulcrum round which the lever turns. The demonstration commonly ascribed to Archimedes is founded upon this principle, that when any cylindric or prismatic body is applied upon a lever, it has the same effect as if its whole weight was united and applied at the middle point of its axis. Let *AB*, *Plate XXXII. Mechanics, fig. 7*, be a cylinder, of an uniform texture, *C* its middle point; and it is manifest, that if the point *C* be supported, the equal halves of the cylinder, *CA* and *CB*, will balance each other about the point *C*, and the body will remain in equilibrio. Let the cylinder *AB* be distinguished into any unequal parts, *AD* and *DB*; bisect *AD* in *E*, and *DB* in *F*; then a power applied at *E*, equal to the weight of the part *AD*, with a contrary direction, will sustain it; and a power applied at *F*, equal to the weight of the part *DB*, with a contrary direction, will sustain that part; so that these two powers acting at *E* and *F*, respectively equal to the weights of *AD* and *DB*, have precisely the same effect as a prop at *C*, sustaining the whole cylinder *AB*, and may be considered as in equilibrio with a power, acting at *C*, equal to the whole weight of the cylinder. But the distance $CE = CA - AE = \frac{1}{2} AB - \frac{1}{2} AD = \frac{1}{2} DB$; and, in like manner, the distance $CF = CB - BF = \frac{1}{2} AB - \frac{1}{2} DB = \frac{1}{2} AD$; consequently *CE* is to *CF* as *DB* to *AD*; that is, as the power applied at *F* to the power applied at *E*, these being in equilibrio with the weight of the whole cylinder applied at *C*. From which it appears, that powers applied at *E* and *F*, which are to each other in the proportion of *CF* to *CE*, sustain one another about the centre *C*.

It has been objected by *M. Huygens* and others, to this demonstration of Archimedes, that when the whole cylinder is distinguished into two segments, part of the weight of the greater segments acts on the same side of the fulcrum with the lesser segment; and, therefore, when the whole weight of the greater segment is contracted into its middle point on one side of the fulcrum, and acts altogether against the lesser segment, it requires some proof to shew, that this contracted weight will be balanced by the weight of the lesser segment. *M. Huygens* proposed a method of his own, depending on a postulatam assumed in common with Archimedes, and needing demonstration, viz. that when equal bodies are placed on the arms of a lever, the one which is farthest from the fulcrum will prevail and raise the other up.

Sir Isaac Newton demonstrates the fundamental proposition concerning the lever, from the resolution of motion: let *C*, *fig. 8*, be the centre of motion in the lever *KL*; let *A* and *B* be any two powers applied to it at *K* and *L*, acting in the directions *KA* and *LB*. From the centre of motion, *C*, let *CM* and *CN* be perpendicular to those directions in *M* and *N*; suppose *CM* to be less than *CN*, and from the centre *C*, at the distance *CN*, describe the circle *NHD*, meeting *KA* in *D*. Let the power *A* be represented by *DA*, and let it be resolved into the power *DG*

acting in the direction *CD*, and the power *DF* perpendicular to *CD*, by completing the parallelogram *AFDG*. The power *DG*, acting in the direction *CD* from the centre of the circle, or wheel, *DHN*, towards its circumference, has no effect in turning it round the centre, from *D* toward *H*, and tends only to carry it off from that centre. It is the part *DF* only that endeavours to move the wheel from *D* towards *H* and *N*, and is totally employed in this effort. The power *B* may be conceived to be applied at *N* as well as at *L*, and to be wholly employed in endeavouring to turn the wheel the contrary way, from *N* towards *H* and *D*. If, therefore, the power *B* be equal to that part of *A* which is represented by *DF*, these efforts, being equal and opposite, must destroy each other's effect; that is, when the power *B* is to the power *A*, as *DF* to *DA*, or (because of the similarity of the triangles, *AFD*, *DMC*) as *CM* to *CD* or as *CM* to *CN*, then the powers must be in equilibrio; and those powers always sustain each other that are in the inverse proportion of the distances of their directions from the centre of motion; or when the product of the one power multiplied by the distance of its direction from the centre, is equal to the product of the power on the other side multiplied by the like distance from it.

Mr. Maclaurin proposes a new method of demonstrating the law of equilibrium in the lever, which seems, he says, to be founded on the plainest and most evident principles: these principles are the following, viz. that if equal powers act at equal distances on different sides of the fulcrum or centre of motion, with directions opposite and parallel to each other, they will have the same effect: and that, if gravity be supposed to act in parallel lines, and the fulcrum be between the bodies, whose powers are estimated, it must bear the sum of their weights; because the lever being loaded with those weights, it must give way, if the fulcrum does not sustain their sum: but if the powers are on the same side of the fulcrum, in which case one of them must pull upwards whilst the other pulls downwards, that there may be an equilibrium, it is then only loaded with the difference of the powers.

Supposing, therefore, first, two equal powers, *A* and *B*, *fig. 9*, acting in the directions *AF*, *BH*, to carry a body *C*, upon the lever *AB*, placed at *C* at equal distances from them; it is evident that, in this case, each of the powers *A* and *B* sustains one-half of the weight *C*, by dividing it equally between them. Imagine now that the power *A* is taken away, and that, instead of resting upon it, the end *A* of the lever rests upon a prop at *A*; it is manifest that the power *B*, and the prop at *A* sustain, as before, each one-half of the weight *C*; the prop now acting, in every respect, as the power at *A* before; and, the equilibrium continuing, it appears that, in this case, a power *B* equal to one-half of the weight *C* sustains and balances it, when the distance of *C* from the prop *A* is one-half of the distance of *B* from the same; that is, when *B* is to *C*, as *CA* to *BA*, or $B \times BA = C \times CA$. From this simple instance we see, that powers act upon a lever not by their absolute force only, but that their effect necessarily depends upon the distance of the point where they act from the prop, or centre of motion; and particularly, that a power balances a double power which acts at half its distance from the prop, on the same side of it, with an opposite direction.

The case when the two powers act on the different sides of the prop, follows from this, by the principles already laid down. For let *BH* and *CG* (*fig. 10.*) represent the directions and forces with which the powers *B* and *C* act upon the lever; upon *BA* produced take *AE* equal to *AC*, or $\frac{1}{2} AB$, and in place of the power *CG* substitute

an equal power $E K$ at E , with an opposite direction; and, by the first of those principles, this power $E K$ will have the same effect as $C G$, only the prop or centre of motion A will now sustain the sum of the forces $E K$ and $B H$, by the second of those principles. But the equilibrium between the powers $B H$ and $E K$ will continue as it was before, between $B H$ and $C G$; so that the powers $B H$ and $E K$ will be in equilibrio, when the power $B H$ is one-half of $E K$, and the distance of $E K$ from the prop A is one-half of the distance of $B H$ from the same; that is, when the power at B is to the power at E , as $A E$ to $A B$, or $B \times B A = E \times E A$. In this case, the prop A being loaded with both the powers B and E , which act with the same direction, its reaction must be equal to their sum, $E K + B H = 3 B H$, and must be in the opposite direction $A F$. In place of this reaction, let us now (*fig. 11.*) substitute a power $A F$ at A , equal to thrice $B H$; and in place of the power $E K$, let us substitute a prop at E , sustaining that end of the lever $B E$; and since the equilibrium continues as before, it follows that the prop or centre of motion, being at E , the power $B H$ sustains the power $A F$, which is triple of $B H$, when the distance of $B H$ from the prop E is triple of the distance of the power $A F$ from the same, that is, when $B H \times B E = A F \times A E$.

If we suppose the power $E K$ to remain (*fig. 12.*) but the end B of the lever $E B$ to rest upon a prop, then the powers $A F$ and $E K$ will sustain and balance each other, the prop at B now coming in place of the power $B H$; in which $A F = 3 B H$, and $E K = 2 B H$; so that $A F$ is to $E K$ as 3 to 2; and the distances $E B$ and $A B$ being in the same proportion, it appears that when two powers in the proportion of three to two act upon a lever on the same side of the prop, or centre of motion, with opposite directions, at distances in the proportion of two to three, they then sustain each other. We have demonstrated therefore, that when the powers are in the proportion either of two to one, or of three to one, or of three to two, and the distances of their application from the centre of motion are in the inverse proportion, then those powers balance each other, or are in equilibrio.

Upon $B E$ produced (*fig. 13.*) take $E L = E A$; and in place of the power $A F$ substitute a power $L M = A F$, but with a contrary direction; this power $L M$ will have the same effect to turn the lever round the centre of motion E as $A F$ had; consequently it will be in equilibrio with the power $B H$, as $A F$ was. Therefore, when two powers $L M$ and $B H$, in the proportion of three to one, act upon a lever with the same direction, they are in equilibrio, if their distances from the centre of motion $L E$ and $E B$ be in the ratio of one to three: that is, when $L M \times L E = B H \times B E$. In this case, the powers $L M$ and $B H$ acting with the same direction, the prop E must sustain their sum $L M + B H = 4 B H$, by the second principle above premised. Therefore a power at L , as 3, and a power acting at B with the same direction, as 1, are sustained by a power acting at E , with a contrary direction, as 4. From which it follows, by substituting in the place of the power $L M$ a prop at L , that a power at B , as 1, sustains a power at E , as 4, acting with a contrary direction, when $B L$ is to $E L$ as 4 to 1; that is, when the powers are inversely as their distances from the prop, or centre of motion. By substituting the prop at B in the place of the power $B H$, it appears that a power $L M$ at L , as 3, sustains a power acting with an opposite direction at E , as 4, when their distances $L B$ and $E B$, from the prop B , are to each other as 4 to 3, or when $L M \times L B = E K \times E B$. By taking upon $L B$ produced $B e = B E$ (*fig. 14.*), and in place of the

power at E , substituting an equal power at e with a contrary direction, it appears, that a power at L , as 3, sustains a power acting at e , with the same direction, as 4, when the distance $L B$ is to the distance $e B$, as 4 to 3. In this case, the prop at B sustains the sum of the powers acting at L and e , that is, a power equal to seven times $B H$. From which it follows, by substituting a prop at L or e , in place of the powers that act there, that a power at e , as 4, sustains a power at B , as 7, about the centre of motion L , when their distances from it, $e L$, $B L$, are to each other as 7 to 4; and that a power at L , as 3, sustains the power at B , as 7, about the centre of motion e , when their distances from it, $L e$ and $B e$, are to each other as 7 to 3.

By proceeding in this manner it appears, that when the powers are to each other as number to number, and when their distances from the centre of motion are in the inverse ratio of the same numbers, then the powers sustain each other, or are in equilibrio. From which it is easy to shew, in general, that when the powers are to each other in any ratio, though incommensurable, and the distances of their application from the centre of motion in the same inverse ratio, then they are in equilibrio; because the ratio of incommensurable quantities may be always limited to any degree of exactness at pleasure, between a greater and a lesser ratio of number to number. To Mr. Maclaurin's demonstration it has been objected, that it cannot be applied when the arms of the lever are incommensurable, and as it cannot conclude generally, it must, therefore, be imperfect.

Dr. Hamilton, having observed that these several methods of demonstrating the fundamental property of the lever are liable to objections, proposes a new proof, depending on the following postulatam, *viz.* if a force be uniformly diffused over a right line, so that an equal part of the force acts upon every point of the line, and if the whole force acts according to one and the same plane, this force will be sustained, and the line kept in equilibrio, by a single force applied to the middle point of the line equal to the diffused force, and acting in a contrary direction. He also premises this lemma: if a right line be divided into two segments, the distances between the middle of the whole line and the middle points of the segments, will be inversely as the segments. This is self-evident when the segments are equal; and, when they are unequal, since half of the whole line is equal to half of the greater and half of the lesser segment, it is plain that the distance between the middle of the whole line and the middle of one segment, must be equal to half of the other segment, so that these distances must be to each other inversely as the segments.

Let the line $G H$, then, *fig. 15*, whose middle point is D , be divided into the unequal segments $G L$ and $L H$, whose middle points are C and F , and let two forces or weights, A and B , which are to each other as the segments $G D$ and $L H$, be applied to their middle points C and F , and let them act perpendicularly on the line $G H$: then, (by the lemma) the weights A and B will be to each other inversely as $C D$ and $F D$ (the distances of the points C and F , to which they are applied, from the middle of the whole line); if then a third force or weight E , equal to the sum of the forces A and B , be applied to the point D , and acts on the line in an opposite direction; I say these three forces will sustain each other, and keep the line in equilibrio. For let us suppose the force E to be removed, and instead of it another force, equal also to the sum of A and B , to be uniformly diffused over the whole line $G H$, and to act directly against the forces A and B , then the part of this force which acts on the segment $G L$, will be equal to the force A , and therefore will be sustained by it (postu-

latum); and the other part, which is diffused over the segment LH , will be equal to and sustained by the force B , so that the forces A and B will sustain this diffused force and keep the line in equilibrio. Let now two other forces act also on this line in opposite directions, one of them the force E acting on the point D , as it was first supposed to do, and the other an uniformly diffused force equal to E (and consequently equal to the other diffused force), then these two additional forces will also balance each other, and therefore the equilibrium will still remain. So that the two forces A and B , and a diffused force acting on one side of the line sustains the force E , and a diffused force acting on the other side: but it is manifest, that in this equilibrium, the two diffused forces acting on opposite sides are perfectly equivalent, and therefore if they are taken away from both sides, the equilibrium must still remain. Hence it appears that the three weights or forces A , B , and E , any two of which are, (by the construction) to each other inversely as their distances from the third, will sustain each other and keep the line on which they act in equilibrio; which is the first and most simple case of the property of the lever; for here the directions of the weights are supposed to be perpendicular to the line on which they act, and it is evident that, if one of the points C , D , or F be fixed or considered as a fulcrum, the weights acting on the other two points will continue to support each other. The second case of the property of the lever is easily deduced from the first; for when two weights act on the arms of a lever in oblique directions, and are to each other inversely as the perpendicular distances of the lines of direction from the centre of motion, then by the resolution of forces, it is easily proved that the parts of those forces which act perpendicularly on the arms of the lever, and which only are exerted to turn the lever, are to each other inversely as the lengths of those arms; and therefore by the first case they must balance each other.

From what has been above demonstrated, it appears, that the powers with which any two forces move or endeavour to move the arms of a lever, are as the rectangles, under lines proportional to the forces, and the perpendicular distances of their lines of direction from the fulcrum; and also that when two bodies acting on the arms of a lever sustain each other, if one of them be removed farther from the fulcrum, it will preponderate; but if it be brought nearer to the fulcrum, the other weight will prevail: because the product to which its force is proportional will be increased in the first case, and diminished in the second.

When a weight is to be raised by means of an axle and wheel, it is fastened to a chord that goes round the axle, and the power, which is to raise it, is hung to a chord that goes round the wheel. If then the power be to the weight as the radius of the axle to the radius of the wheel, it will just support that weight; as will easily appear from what was proved of the lever. For the axle and wheel may be considered as a lever, whose fulcrum is a line passing through the centre of the wheel and middle of the axle, and whose long and short arms are the radii of the wheel and axle which are parallel to the horizon, and from whose extremities the chords hang perpendicularly. And thus an axle and wheel may be looked upon as a kind of perpetual lever, on whose arms the power and weight always act perpendicularly, though the lever turns round its fulcrum. And in like manner, when wheels and axles move each other by means of teeth on their peripheries, such a machine is really a perpetual compound lever; and, by considering it as such, we may compute the proportion of any power to the weight it is able to sustain by the help of such an engine. And since the radii of two contiguous wheels, whose teeth are applied to each other, are as

the number of teeth in each, or inversely as the number of revolutions, which they make in the same time: we may, in the computation, instead of the ratio of these radii, put the ratio of the number of teeth on each wheel; or the inverse ratio of the number of revolutions they make in the same time.

The most natural method of explaining the effects of the pulley, that is, of computing the proportion of any power to the weight it can sustain by means of any system of pulleys, is, by considering that every moveable pulley hangs by two ropes equally stretched, which must bear equal parts of the weight: and, therefore, when one and the same rope goes round several fixed and moveable pulleys, since all its parts on each side of the pulleys are equally stretched, the whole weight must be divided equally amongst all the ropes by which the moveable pulleys hang. And consequently if the power which acts on one rope be equal to the weight divided by the number of ropes, or double the number of moveable pulleys, that power must sustain the weight.

The several cases in which the wedge is applied may be comprehended in one general proposition: let the equicrural triangle ABC (*fig. 16.*) represent a wedge, the lines AB and CB will be the sides of the wedge, AC its base, or back, and its height will be the line PB bisecting the base AC , and also the vertical angle ABC .

When any two resisting forces act on the sides of a wedge, in directions which make equal angles with the sides, (as they are always supposed to do,) a power acting perpendicularly at P on the base of the wedge will keep the resisting forces in equilibrio, when it is to the sum of these forces, as the sine of half the vertical angle of the wedge, to the sine of the angle which the directions of the forces contain with the sides of the wedge.

For let E and F be two bodies acting on the sides of the wedge, and let them be first supposed to act in the directions EP and FP perpendicular to the sides; then since the power P acts perpendicularly on the base AC , if these three forces keep the wedge in equilibrio, they will be to each other, as the sides of a triangle to which their directions are parallel, or (which is the same thing) as the sides of the triangle ABC , to which their directions are perpendicular. Therefore, the power P is to the sum of the resisting forces which it sustains as AC , the base of the wedge, to the sum of the sides, or as PA , half the base, to AB , one of the sides; but PA is to AB as the sine of PBA , half the vertical angle of the wedge, to the radius which is the sine of a right angle, and the directions of the resisting forces are supposed in this case to contain a right angle with the sides of the wedge.

Let now the resisting bodies E and F be supposed to act on the wedge in directions parallel to the lines DP and OP , which make oblique angles with its sides, draw EG and FK perpendicular to those lines. From what has been proved, it appears that the power P is to the force with which it is able, by means of the wedge, to protrude the resisting bodies in the directions PE and PF , as the sine of half the vertical angle to the radius; let this protruding force be expressed by the line PE , and let it be resolved into two forces expressed by the lines PG and GE , the former of these only will act in opposition to the resisting bodies, therefore the whole protruding force of the power is to the force with which it acts against the resisting bodies E and F in the directions PD and PO as PE to PG , or (because the triangles EPG and DPE are similar) as PD to PE , that is, as the radius to the sine of the angle PDE ; compounding, therefore, the ratio of the sine of half the vertical angle to the radius, with the ratio of the radius to the sine of the angle PDE ,

the power P , when the wedge is kept in equilibrio, will be to the force with which it protrudes the resisting bodies in directions opposite to those in which they act, as the sine of half the vertical angle to the sine of the angle PDE or POF , which the directions of the resisting forces contain with the sides of the wedge.

Hence, when the directions in which resisting bodies act on a wedge are given, we may easily find two lines that will express the proportion between the resistance and the power which sustains it by means of the wedge. For from P , the middle point of the wedge, draw the line PD meeting one of the sides, and parallel to the direction in which the resisting force acts on that side, then the power will be to the resistance as PD to PB the height of the wedge. For PD and PB are to each other as the sines of the opposite angles, in the triangle PBD , that is, as the sines of half the vertical angle, and the angle which the direction of the resisting force contains with the side of the wedge.

From what has been demonstrated we may deduce the proportion of the power to the resistance it is able to sustain, in all the cases in which the wedge is applied.

First, when, in cleaving timber, the wedge fills the cleft, then the resistance of the timber acts perpendicularly on the sides of the wedge; therefore, in this case, when the power which drives the wedge is to the cohesive force of the timber as half the base to one side of the wedge, the power and resistance will be in equilibrio.

Secondly, when the wedge does not exactly fill the cleft, which generally happens because the wood splits to some distance before the wedge: let ELF represent a cleft, into which the wedge ABC is partly driven; as the resisting force of the timber must act on the wedge in directions perpendicular to the sides of the cleft, draw the line PD in a direction perpendicular to EL , the side of the cleft, and meeting the side of the wedge in D ; then the power driving the wedge, and the resistance of the timber, when they balance, will be to each other as the line PD to PB , the height of the wedge.

Thirdly, when a wedge is employed to separate two bodies that lie together on a horizontal plane, for instance two blocks of stone; as these bodies must recede from each other in horizontal directions, their resistance must act on the wedge in lines parallel to its base CA ; therefore, the power which drives the wedge will balance the resistance, when they are to each other as PA , half the breadth of the wedge, to PB its height; and then any additional force, sufficient to overcome the resistance arising from the friction of the bodies on the horizontal plane, will separate them from each other.

With respect to the inclined plane: let the line AB , (*fig. 17.*) represent the length of an inclined plane, AD its height, and the line BD we may call its base. Let the circular body $G-EF$ be supposed to rest on the inclined plane, and to be kept from falling down it by a string CS tied to its centre C . Then the force with which this body stretches the string will be to its whole weight as the sine of ABD , the angle of elevation, to the sine of the angle which the string contains with a line perpendicular to AB , the length of the plane. For let the radius CE be drawn perpendicular to the horizon, and CF perpendicular to AB , and from E draw EO parallel to the string, and meeting CF in O : then, as the body continues at rest, and is urged by three forces, to wit, by its weight in the direction CE , by the re-action of the plane in the direction FC , and by the re-action of the string in the direction EO ; the re-action of the string, or the force by which it is stretched, is to the weight of the body as EO to CE ; that is, as the sine of

(the angle ECO , which is equal to) ABD , the angle of elevation, to the sine of the angle EOC , equal to SCO , the angle which the string contains, with the line CF perpendicular to AB , the length of the plane.

When, therefore, the string is parallel to the length of the plane, the force with which it is stretched, or with which the body tends down the inclined plane, is to its whole weight, as the sine of the angle of elevation to the radius, or as the height of the plane to the length. And in the same manner it may be shewn, that when the string is parallel to BD , the base of the plain, the force with which it is stretched is to the weight of the body as AD to BD , that is, as the height of the plane to its base. If we suppose the string, which supports the body $G-EF$, to be fastened at S , and that a force by acting on the line AD , the height of the plane, in a direction parallel to the base BD , drives the inclined plane under the body, and by that means makes it rise to a direction parallel to AD : then, from what was proved in the third case of the wedge, it will appear, that this force must be to the weight of the body as AD to BD , or rather in a proportion somewhat greater; if it makes the plane move on and the body rise.

From this last observation we may clearly shew the nature and force of the screw; a machine of great efficacy in raising weights, or in pressing bodies closely together. For if the triangle ABD be turned round a cylinder whose periphery is equal to BD , then the length of the inclined plane BA will rise round the cylinder in a spiral manner, and form what is called the thread of the screw, and we may suppose it continued in the same manner round the cylinder, from one end to the other; and AD , the height of the inclined plane, will be every where the distance between two contiguous threads of this screw, which is called a convex screw. And a concave screw may be formed to fit this exactly, if an inclined plane every way like the former be turned round the inside of a hollow cylinder, whose periphery is somewhat larger than that of the other. Let us now suppose the concave screw to be fixed, and the convex one to be fitted into it, and a weight to be laid on the top of the convex screw: then, if a power be applied to the periphery of this convex screw to turn it round, at every revolution the weight will be raised up through a space equal to the distance between the two contiguous threads, that is, to the line AD , the height of the inclined plane BA ; therefore, since this power applied to the periphery acts in a direction parallel to BD , it must be to the weight it raises as AD to BD , or as the distance between two contiguous threads, to the periphery of the convex screw.

The distance between two contiguous threads is to be measured by a line parallel to the axle; if we now suppose that a handspike or handle is inserted into the bottom of the convex screw, and that the power which turns the screw is applied to the extremity of this handle, which is generally the case; then as the power is removed farther from the axis of motion, its force will be so much increased, and therefore so much may the power itself be diminished. So that the power which, acting on the end of a handle, sustains a weight by means of a screw, will be to that weight, as the distance between two contiguous threads of the screw, to the periphery described by the end of the handle. In this case we may consider the machine as composed of a screw and a lever, or, as sir Isaac Newton expresseth it, *Cuneus a velle impulsus*.

Professor Vince, premising that Dr. Hamilton's demonstration depends upon this proposition, that when a body is at rest, and acted upon by three forces, they will be as the three sides of a triangle parallel to the directions of the

forces, allows this principle to be true, when the three forces act at any point of a body; but, considering the lever as the body, the three forces act at different points, and therefore the principle, as applied by the author, is certainly not applicable. If in this demonstration we suppose a plane body, in which the three forces act, instead of simply a lever, then the three forces being actually directed to the same point of the body, the body would be at rest. But in reasoning from this to the case of the lever, the same difficulties would arise, as in the proof of sir I. Newton. But admitting that all other objections could be removed, the demonstration fails when any two of the forces are parallel. Another demonstration is founded upon this principle, that if two non-elastic bodies meet with equal quantities of motion, they will, after impact, continue at rest; and hence it is concluded, that if a lever which is in equilibrio be put in motion, the motions of the two bodies must be equal; and therefore the pressures of these bodies upon the lever at rest, to put it in motion, must be as their motions. Now in the first place, this is comparing the effects of pressure and motion, the relation of the measures of which, or whether they admit of any relation, we are totally unacquainted with. Moreover, they act under very different circumstances; for in the former case, the bodies acted immediately on each other, and in the latter, they act by means of a lever, the properties of which we are supposed to be ignorant of. When forces act on a body, considered as a point, or directly against the same point of any body, we only estimate the effect of these forces to move the body out of its place, and no rotatory motion is either generated, or any causes to produce it, considered in the investigation. When we, therefore, apply the same proposition to investigate the effect of forces to generate a rotatory motion, we manifestly apply it to a case which is not contained in it, nor to which there is a single principle in the proposition applicable. The demonstration given by Mr. Landen, in his Memoirs, is founded upon self-evident principles, nor does our author see any objections to his reasoning upon them. But as his investigation consists of several cases, and is besides very long and tedious, something more simple is still much to be wished for, proper to be introduced in an elementary treatise of mechanics, so as not to perplex the young student either by the length of the demonstration, or want of evidence in its principles. What the ingenious Professor proposes to offer will, he hopes, render the whole business not only very simple, but also perfectly satisfactory.

The demonstration given by Archimedes would be very satisfactory and elegant, provided the principle on which it is founded could be clearly proved; viz. *that two equal powers at the extremities, or their sum at the middle of a lever, would have equal effects to move it about any point.* Now, that the effects will be the same, so far as respects any *progressive* motion being communicated to the lever when at liberty to move freely, is sufficiently clear; but there is no evidence whatever that the effects will be the same to give the lever a *rotatory* motion about any point, because a very different motion is then produced, and we are supposed to know nothing about the efficacy of a force at different distances from the fulcrum to produce such a motion. Besides, the two motions are not only different, but the *same* forces are known

to produce *different* effects in the two cases; for in the former case the two *equal* powers at the extremities of the arms produce *equal* effects in generating a *progressive* motion; but in the latter case they do *not* produce *equal* effects in generating a *rotatory* motion. We cannot therefore reason from one to the other. The principle, however, may be thus proved.

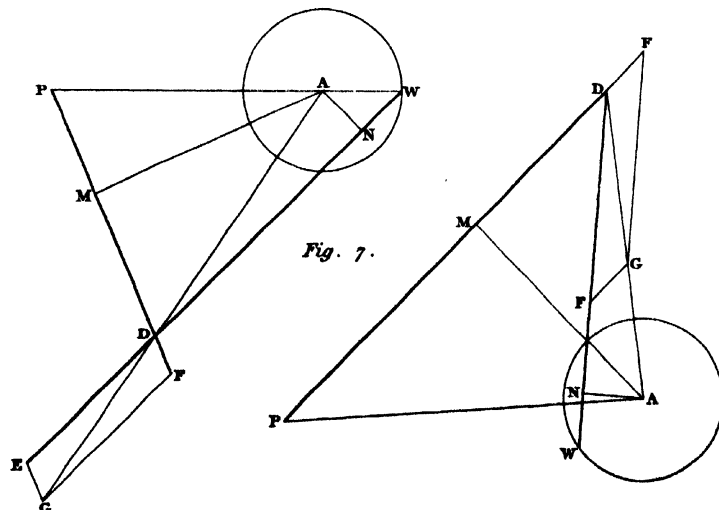
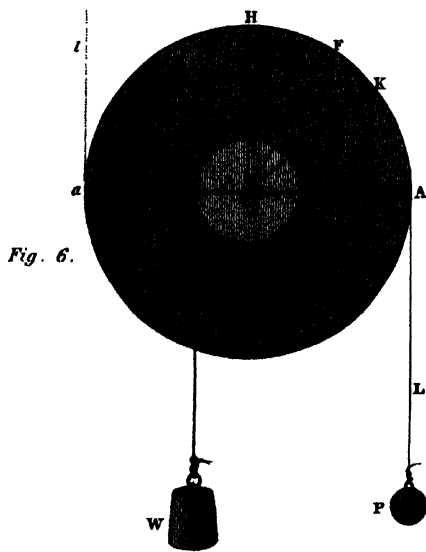
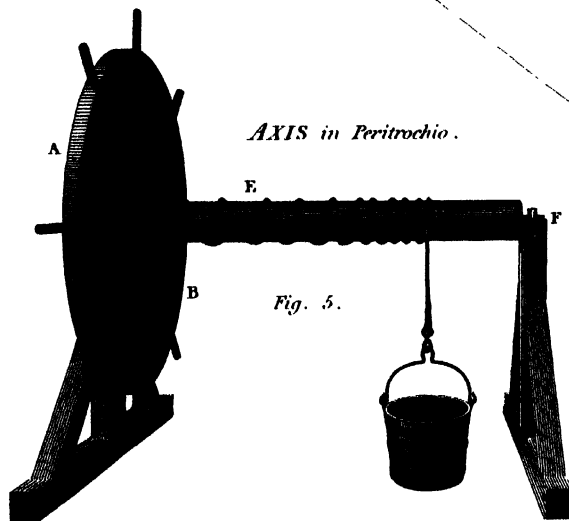
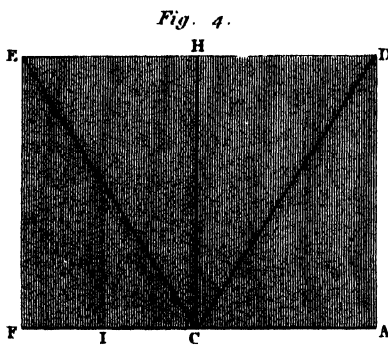
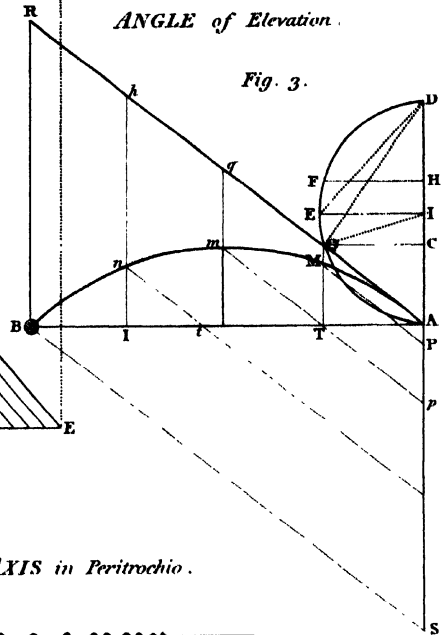
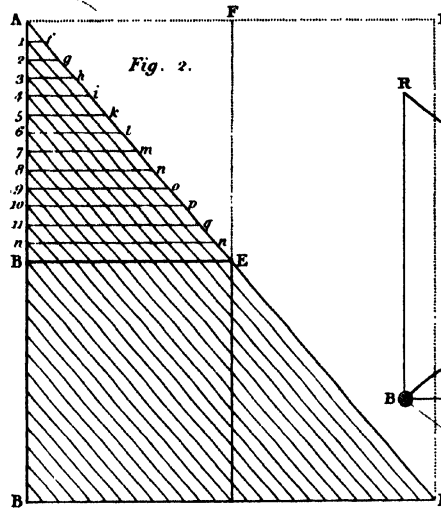
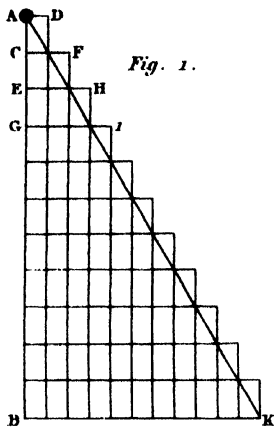
Let A, C, (*fig. 18.*) be two equal bodies placed on a straight lever, A P, moveable about P; bisect A C in B, produce P A to Q, and take B Q = B P, and suppose the end Q to be sustained by a prop. Then as A and C are similarly situated in respect to each end of the lever, that is, A P = C Q, and A Q = C P, the prop and fulcrum must bear equal parts of the whole weight; and therefore the prop at Q will be pressed with a weight equal to A. Now take away the weights A and C, and put a weight at B equal to their sum; and then the weight at B being equally distant from Q and P, the prop and fulcrum must sustain equal parts of the whole weight, and therefore the prop will now also sustain a weight equal to A. Hence if the prop Q be taken away, the moving force to turn the lever about P in both cases must evidently be the same; therefore the effects of A and C upon the lever to turn it about any point are the same as when they are both placed in the middle point between them. And the same is manifestly true if A and C be placed without the fulcrum and prop. If, therefore, A C be a cylindrical lever of uniform density, its effect to turn itself about any point will be the same as if the whole were collected into the middle point B; which follows from what has been already proved, by conceiving the whole cylinder to be divided into an infinite number of laminæ perpendicular to its axis, of equal thicknesses.

The principle, therefore, assumed by Archimedes is thus established upon the most self-evident principle, that is, that *equal* bodies at *equal* distances must produce *equal* effects; which is manifest from this consideration, that when *all* the circumstances in the cause are equal, the effects must be equal. Thus the whole demonstration of Archimedes is rendered perfectly complete, and at the same time it is very short and simple. The other part of the demonstration we shall here insert, for the use of those who may not be acquainted with it.

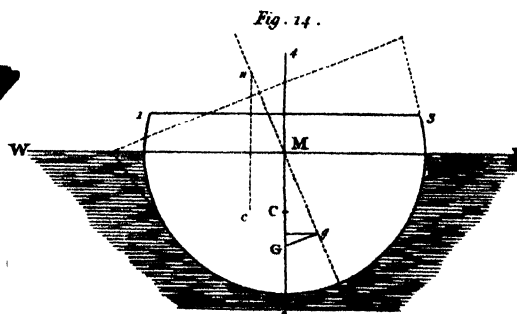
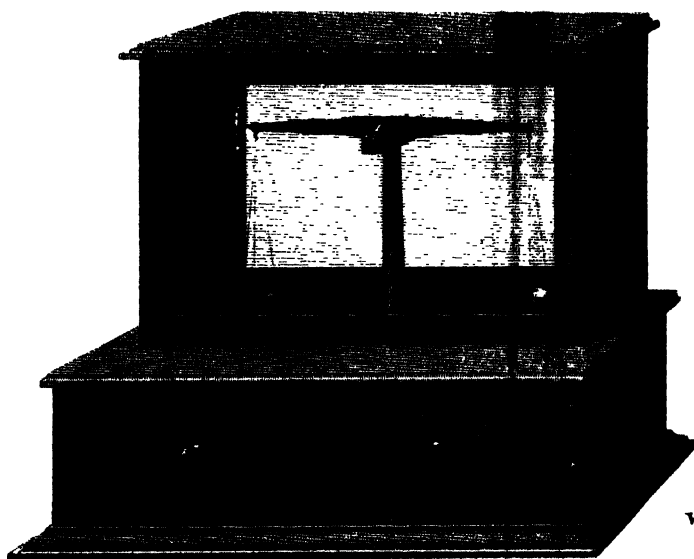
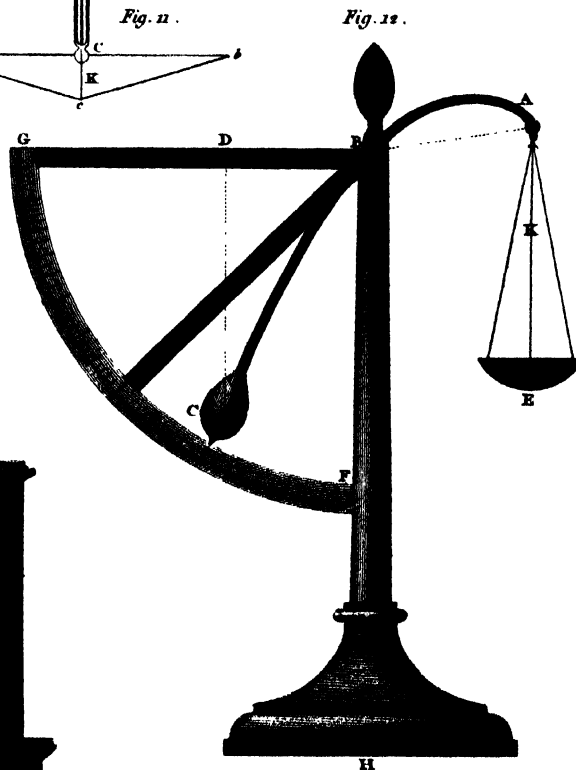
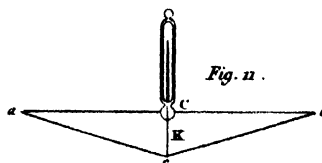
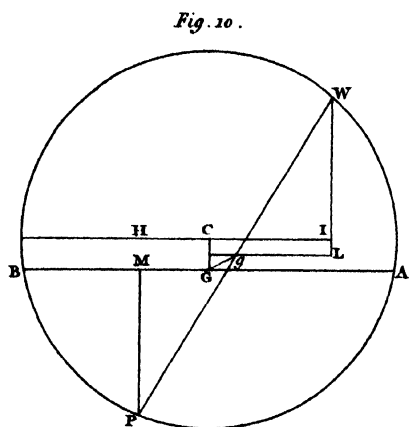
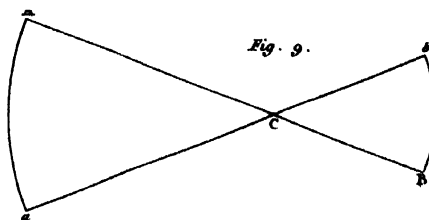
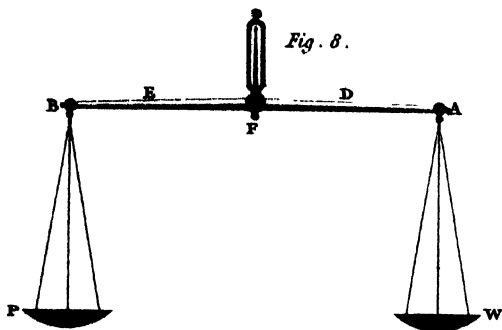
Let X Y (*fig. 19.*) be a cylinder, which bisect in A, on which point it would manifestly rest. Take any point Z, and bisect Z X in B, and Z Y in C; then, from what has been proved, the effects of the two parts Z X, Z Y to turn the lever about A is the same as if the weight of each part were collected into B and C respectively, which weights are manifestly as Z X, Z Y, and which therefore conceive to be placed at B and C. Now A B = A X - X B = $\frac{1}{2}$ X Y - $\frac{1}{2}$ X Z = $\frac{1}{2}$ Y Z; and A C = A Y - Y C = $\frac{1}{2}$ X Y - $\frac{1}{2}$ Z Y = $\frac{1}{2}$ X Z; consequently A B : A C :: $\frac{1}{2}$ Y Z : $\frac{1}{2}$ X Z :: Y Z : X Z :: the weight at C : the weight at B.

The property of the straight lever being thus established, every thing relative to the bent lever immediately follows. See Maclaurin's Account of sir Isaac Newton's Phil. Disc. book ii. chap. 3. Hamilton's Phil. Ess. ess. 1. or Phil. Trans. liii. p. 116. Phil. Trans. vol. lxxxiv. art. v. p. 33, &c.

ACCELERATION.

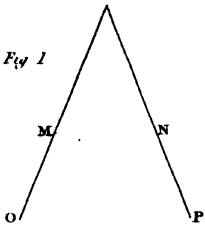


MECHANICS.



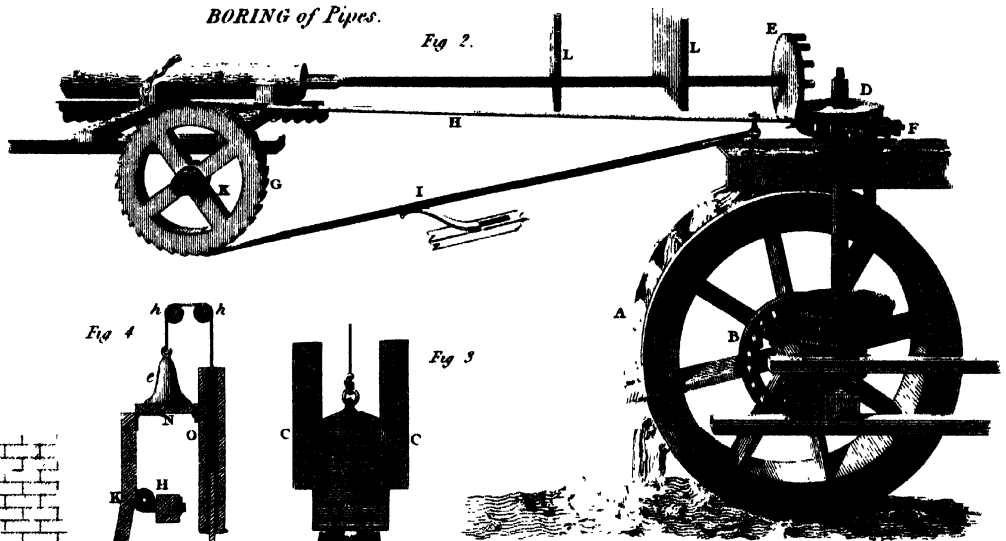
ANGULAR MOTION.

Fig 1

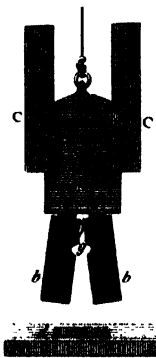
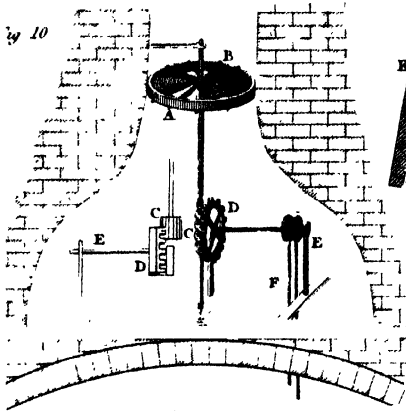


BORING of Pipes.

Fig 2.

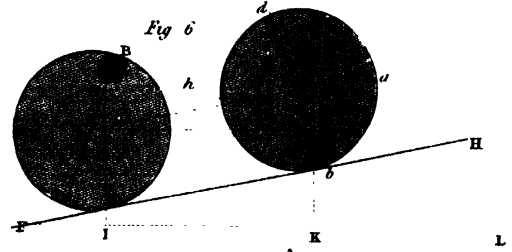


Smoke JACK



Double CYLINDER

Fig 6



CRAB.

Fig 5



LEVER

Fig 13

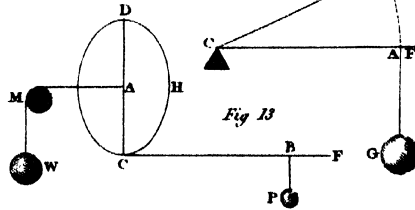


Fig 12

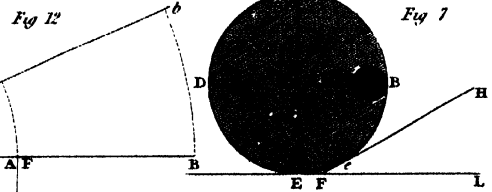
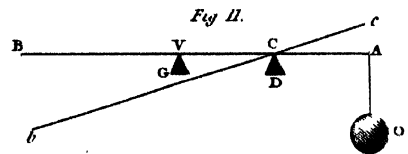


Fig 7

Fig 11



PROJECTILES.

Fig. 17.

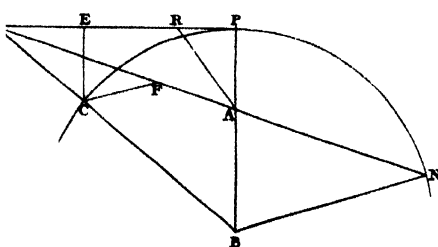


Fig. 15.

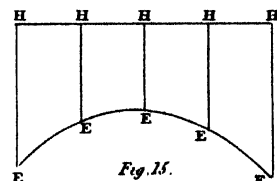


Fig 16

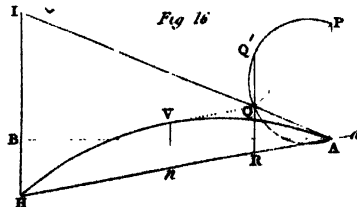
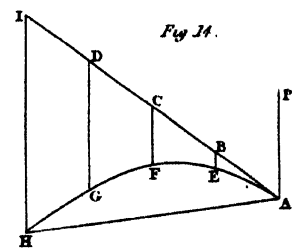


Fig 14.



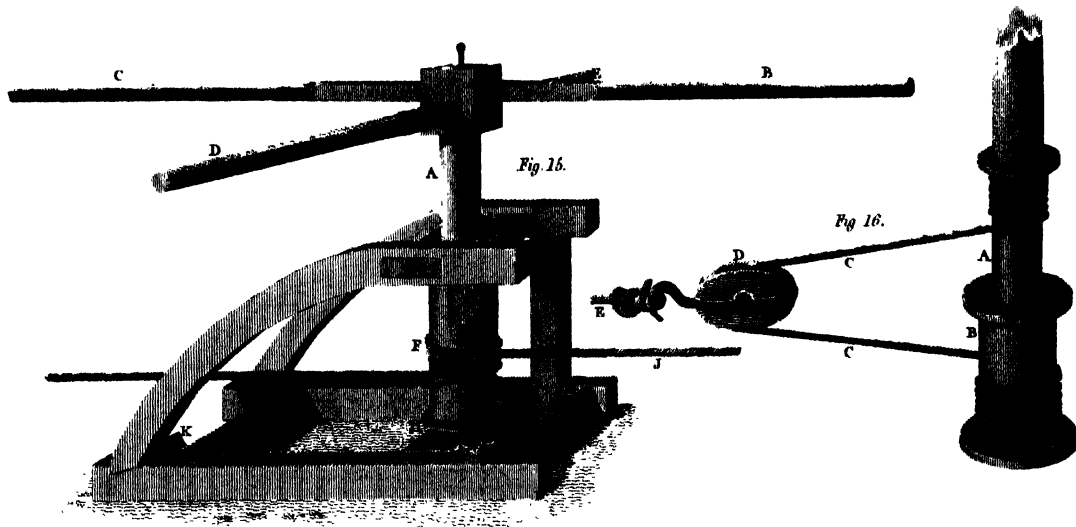


Fig. 20.

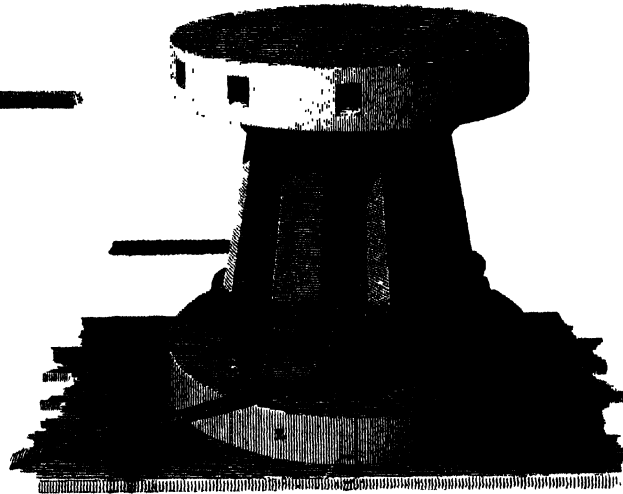


Fig. 17.

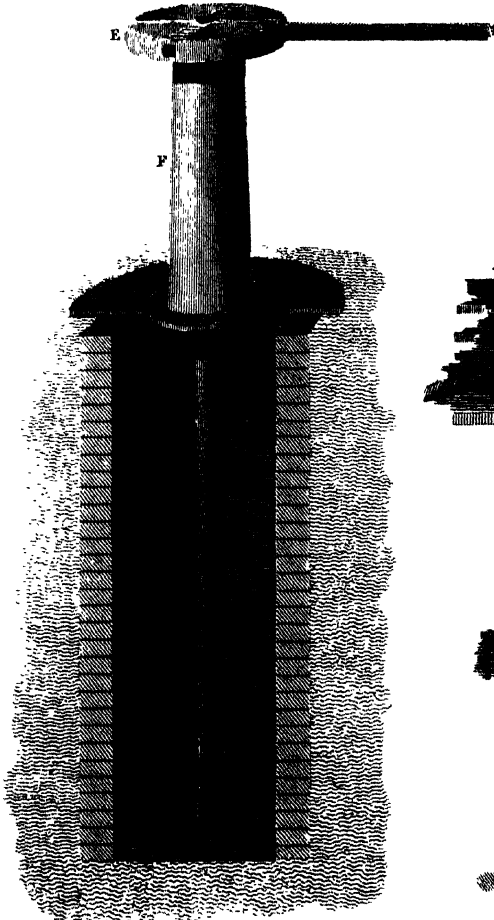


Fig. 18.

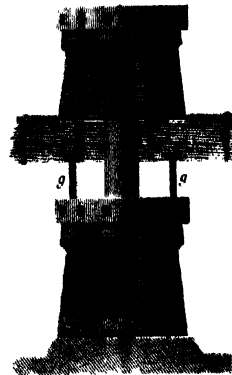


Fig. 19.

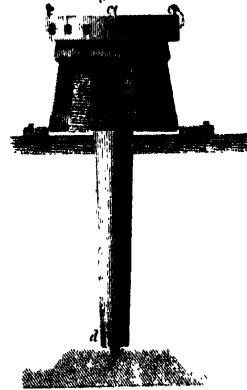
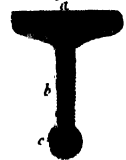


Fig. 22.



MECHANICS.

CENTER OF FRICTION, CENTER OF GRAVITY &c

Fig. 21.

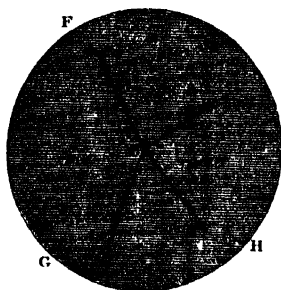


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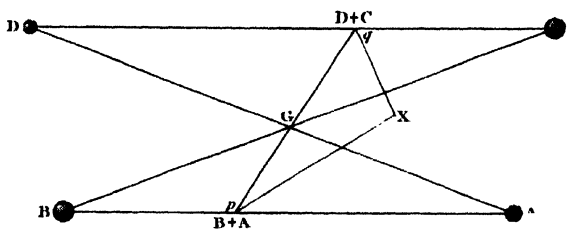


Fig. 23.



Fig. 24.

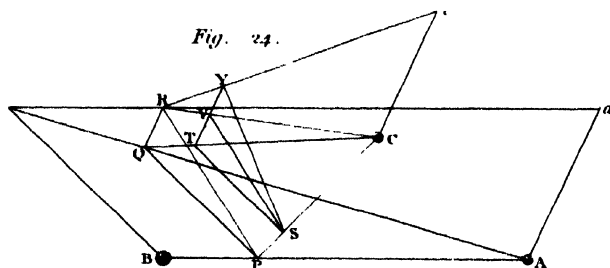


Fig.

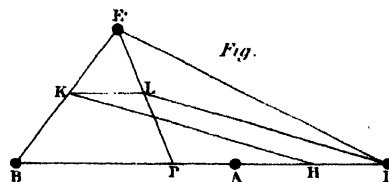


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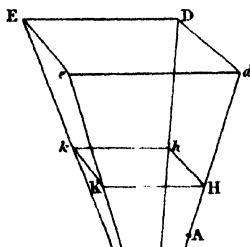


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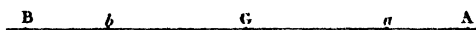


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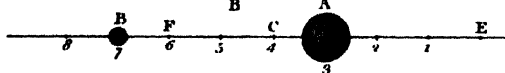
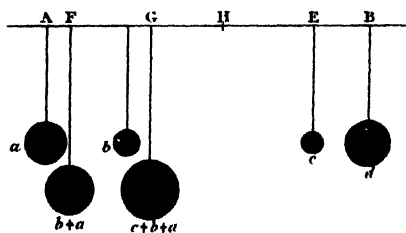
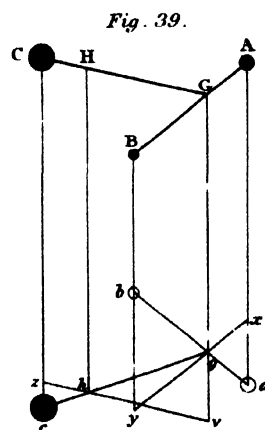
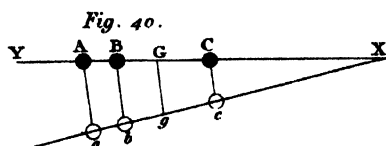
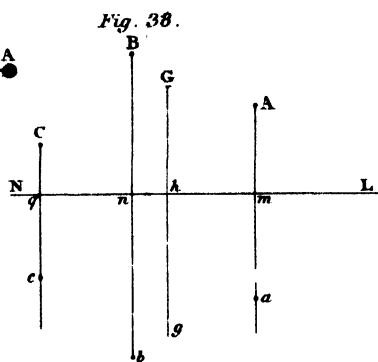
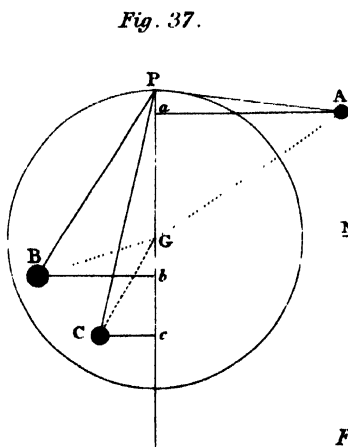
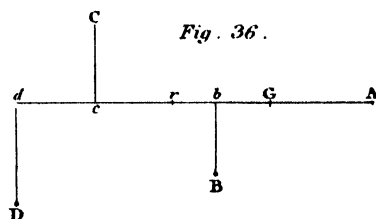
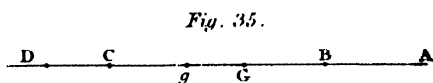
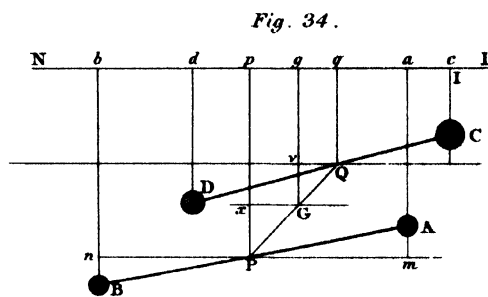
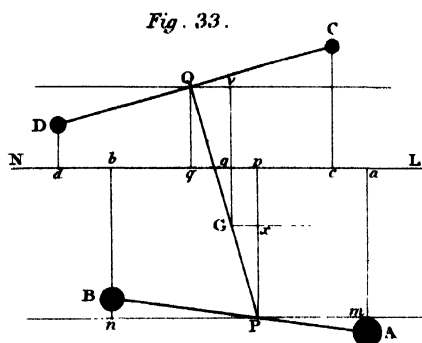
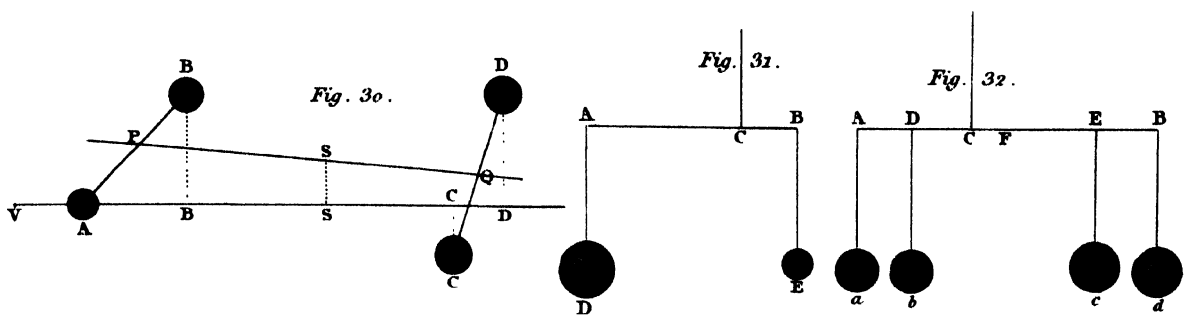


Fig. 29.



CENTER OF GRAVITY.



MECHANICS.

PLATE VI.

CENTER OF GRAVITY.

Fig. 41.

C

Fig. 42.

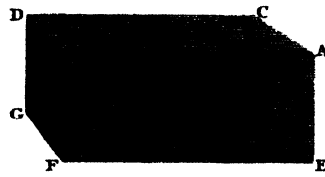


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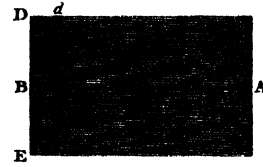


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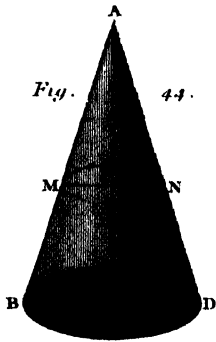


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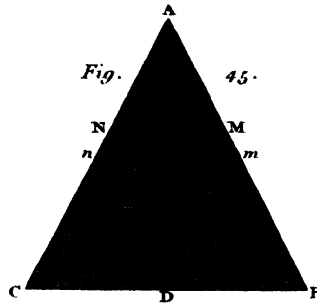


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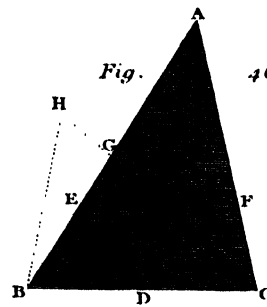


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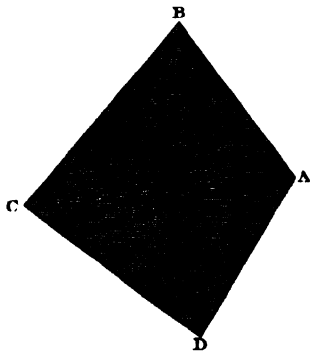


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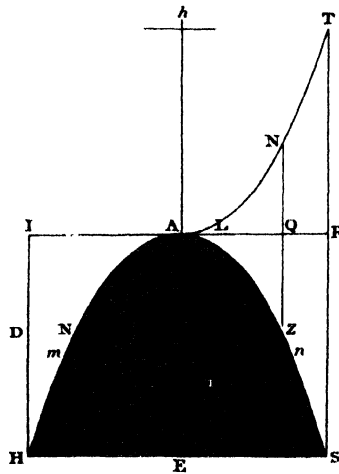


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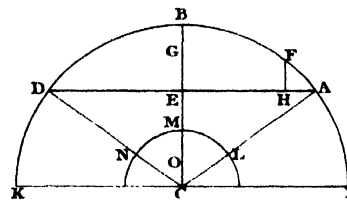


Fig. 50.

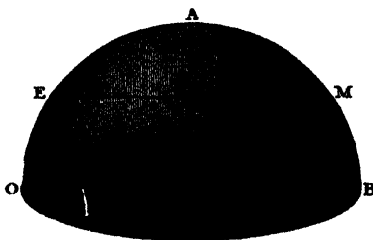
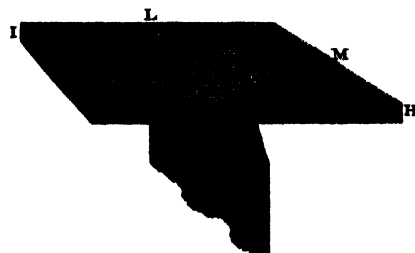


Fig. 51.



MECHANICS.

PLATE VII.

CENTER OF GYRATION, OSCILLATION &c.

Fig. 52.

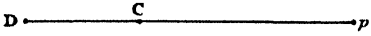


Fig. 53.

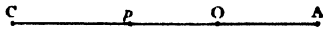


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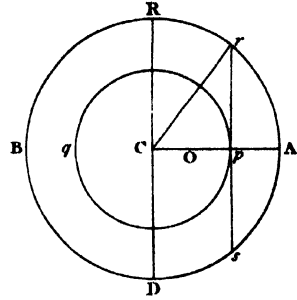


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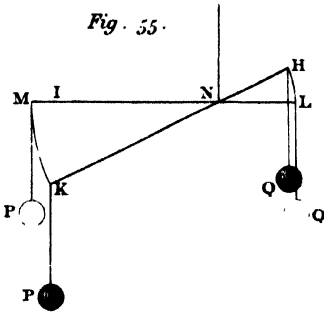


Fig. 56.



Fig. 57.

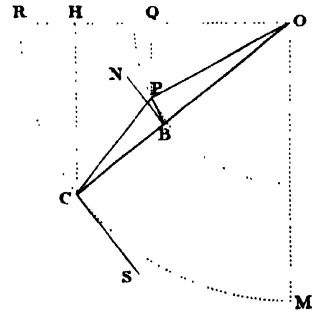


Fig. 58.

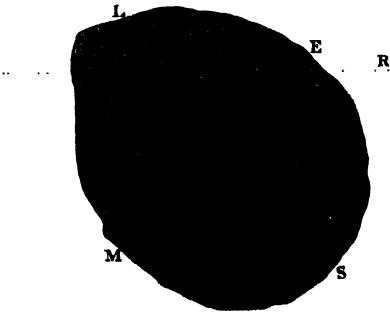


Fig. 59.

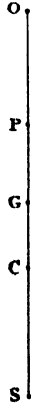
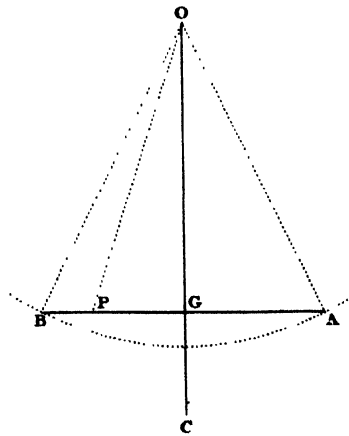


Fig. 60.



CENTER OF OSCILLATION AND CENTER OF PERCUSSION.

Fig. 61.

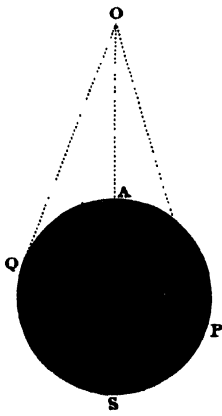


Fig. 62.

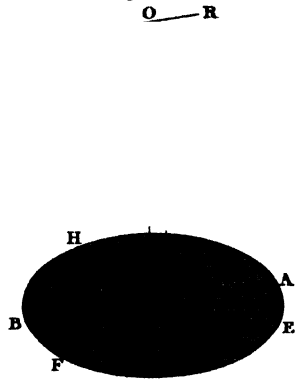


Fig. 63.

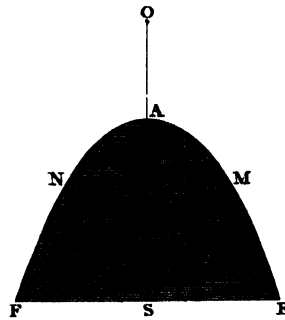


Fig. 64.

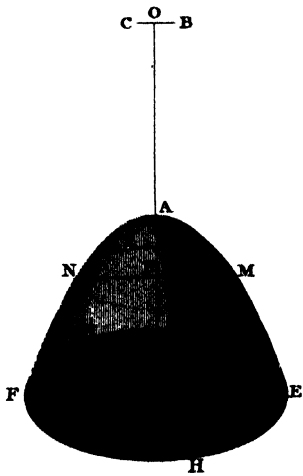


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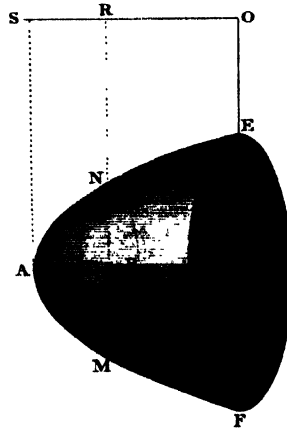


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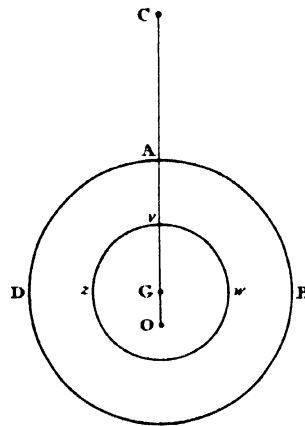


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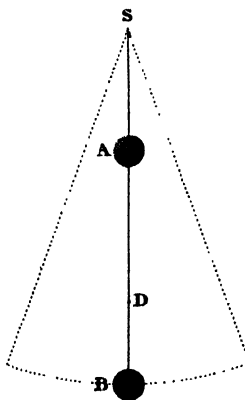


Fig. 69.

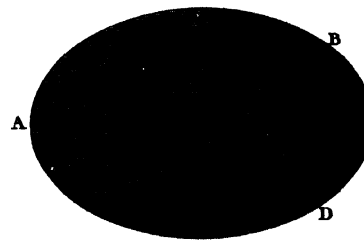
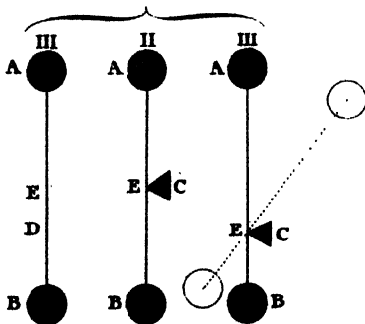
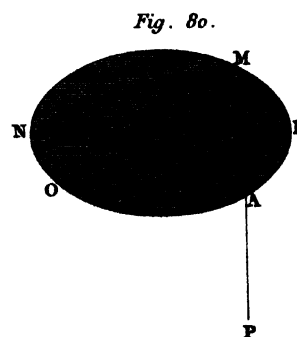
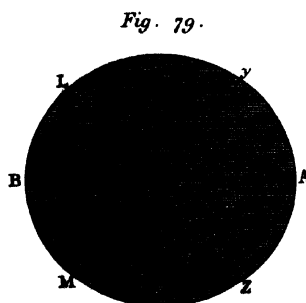
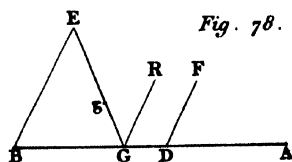
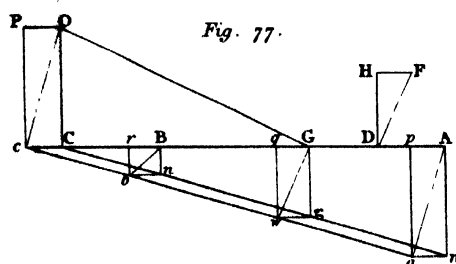
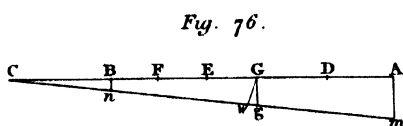
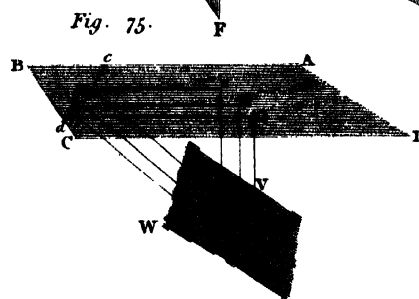
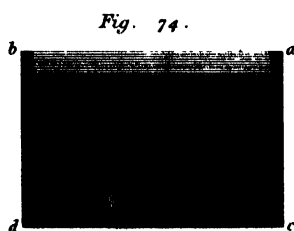
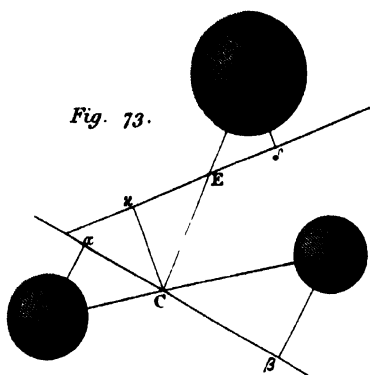
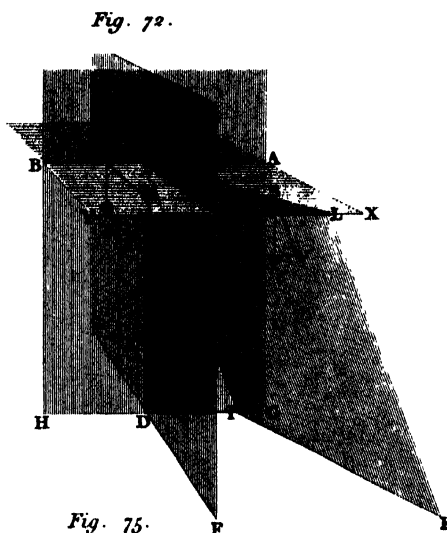
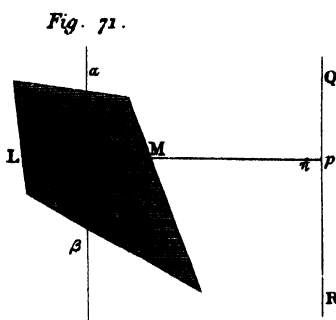
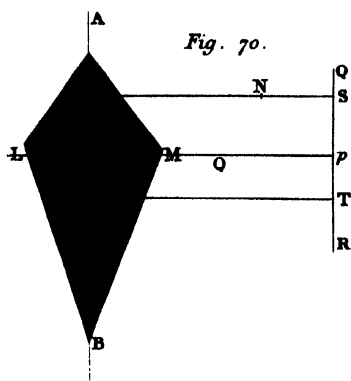


Fig. 67.



CENTER OF POSITION, OF PRESSURE, OF ROTATION &c.



CENTRAL, CENTRIFUGAL, AND CENTRIPETAL FORCES.

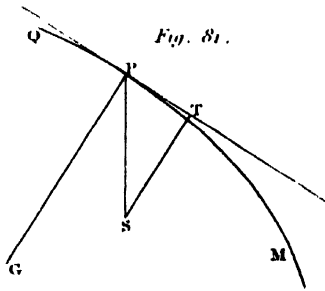


Fig. 81.

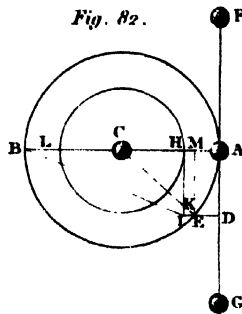


Fig. 82.

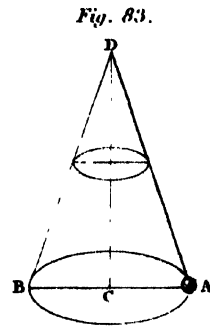


Fig. 83.

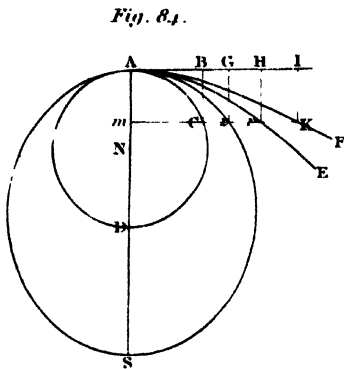


Fig. 84.

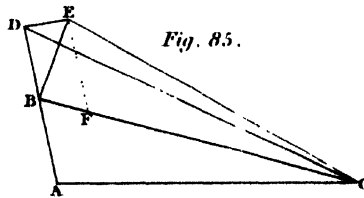


Fig. 85.

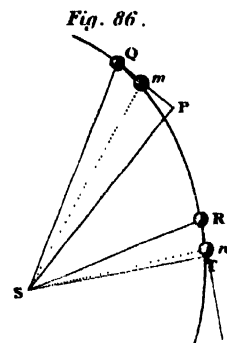


Fig. 86.

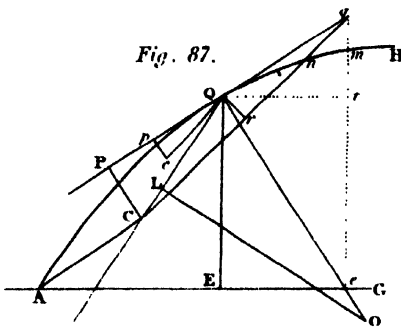


Fig. 87.

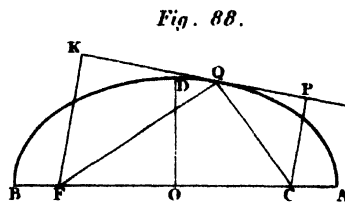


Fig. 88.

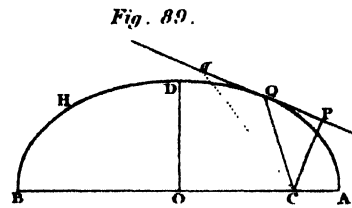


Fig. 89.

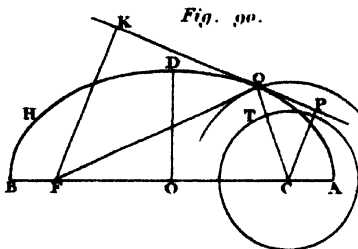


Fig. 90.

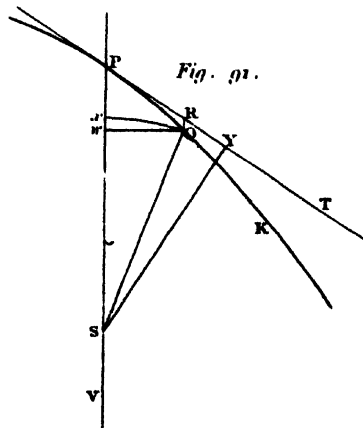


Fig. 91.

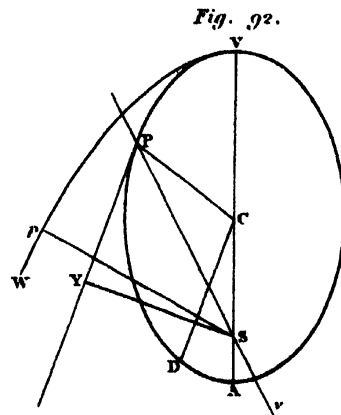


Fig. 92.

CENTRIFUGAL MACHINE AND CENTROBARYC METHOD.

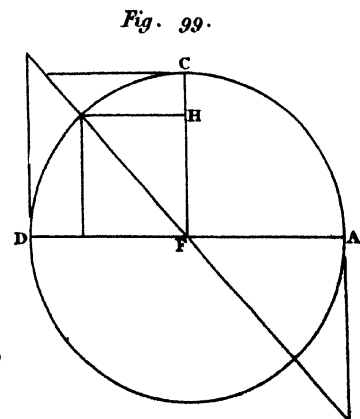
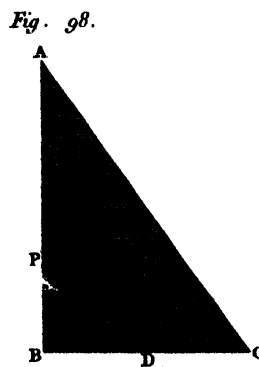
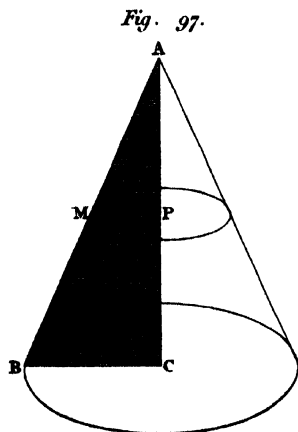
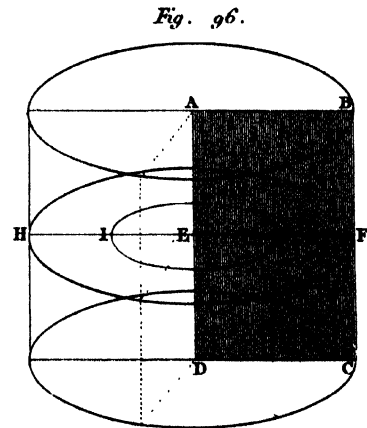
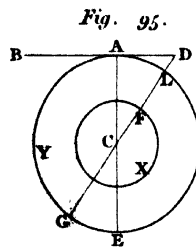
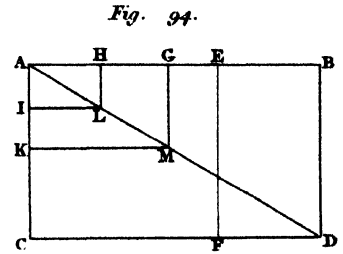
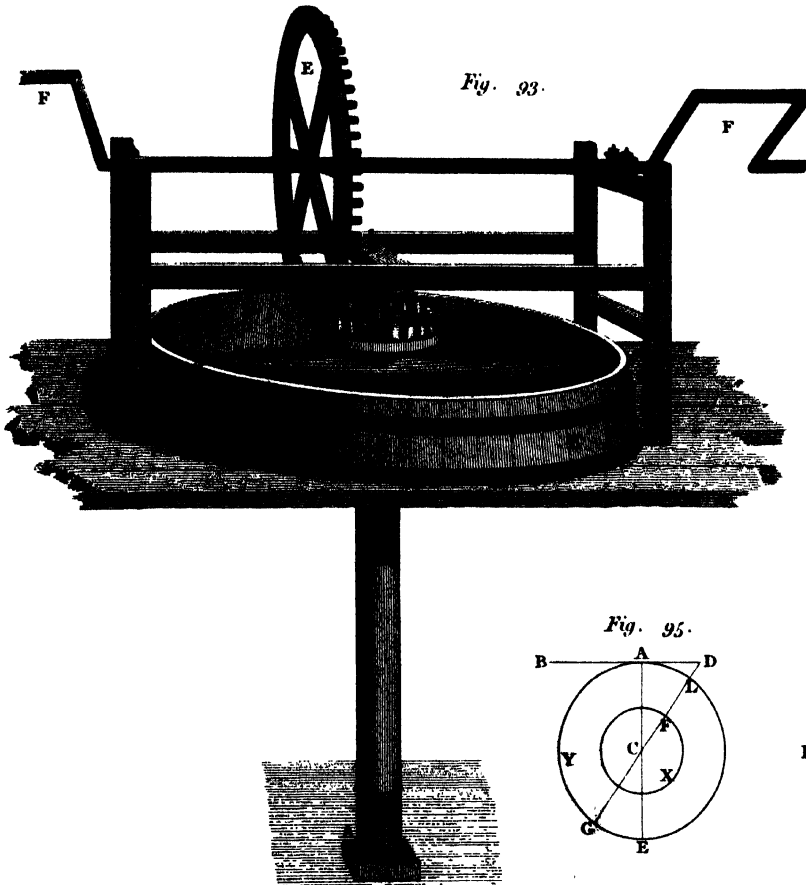


Fig 1.

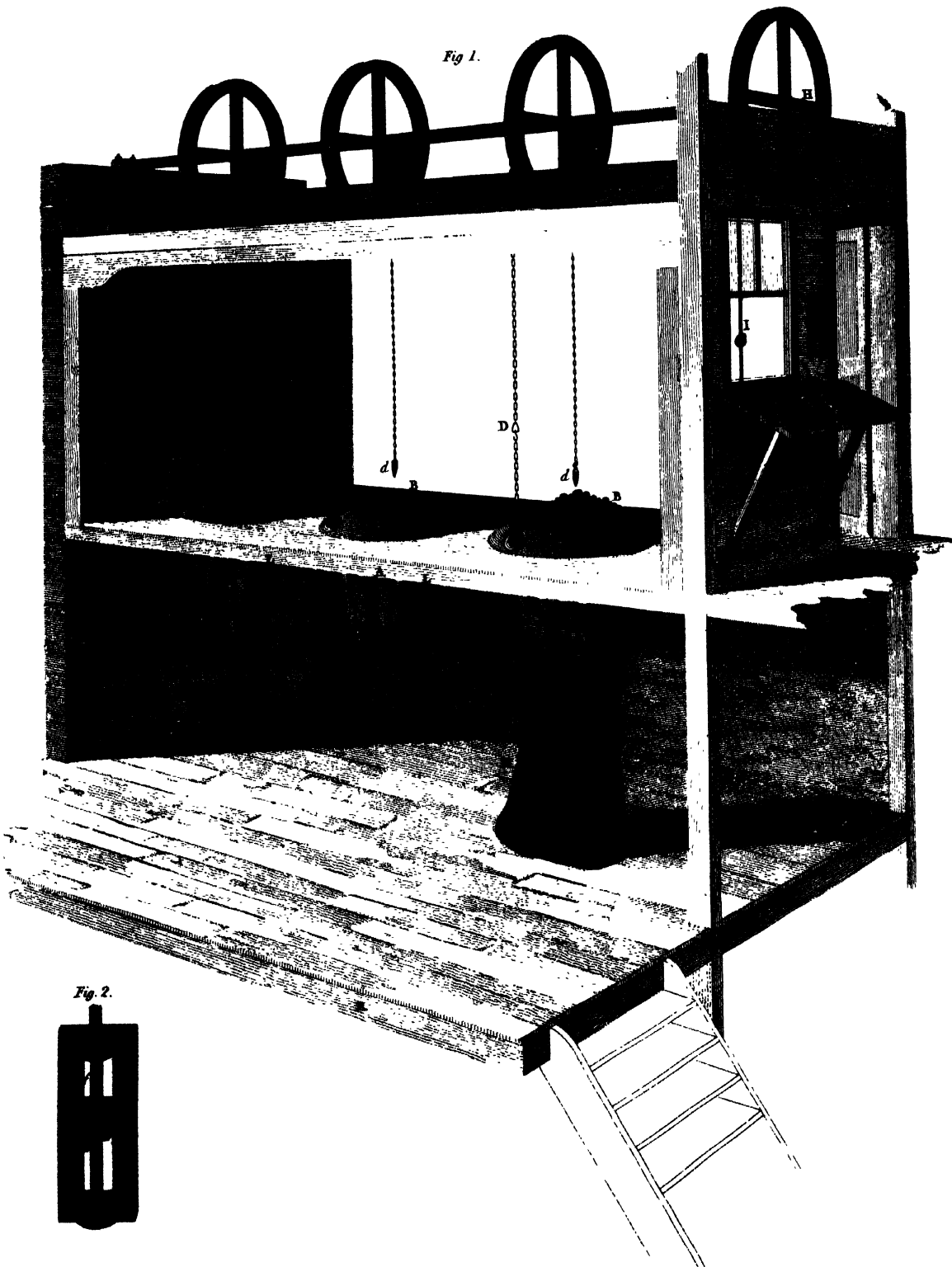


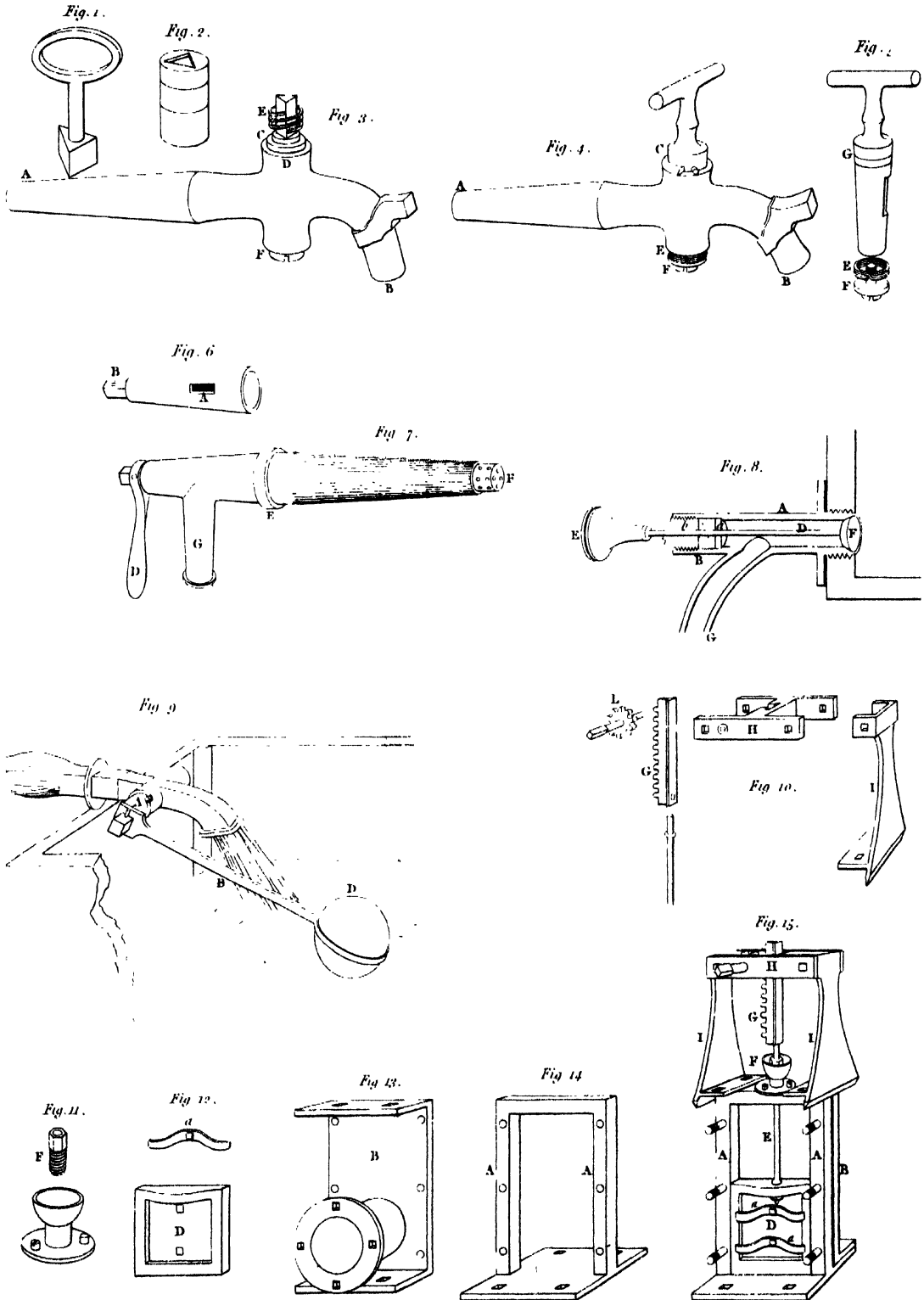
Fig. 2.



MECHANICS.

PLATE XIV.

WATER COCKS.



Prony's Condenser of Forces.

Composition of Motion.

Fig. 10.

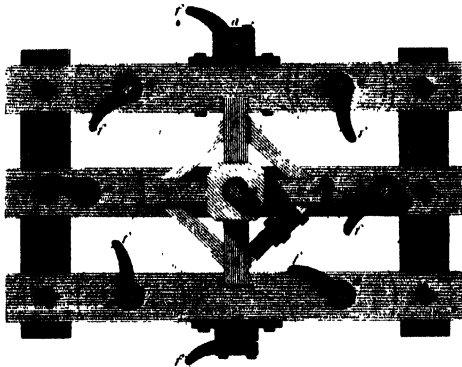


Fig. 1.

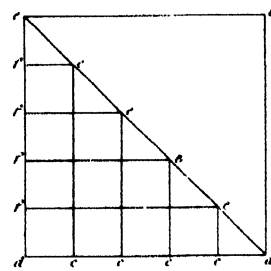
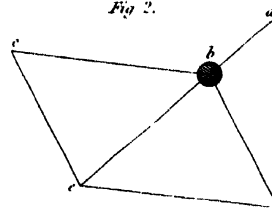
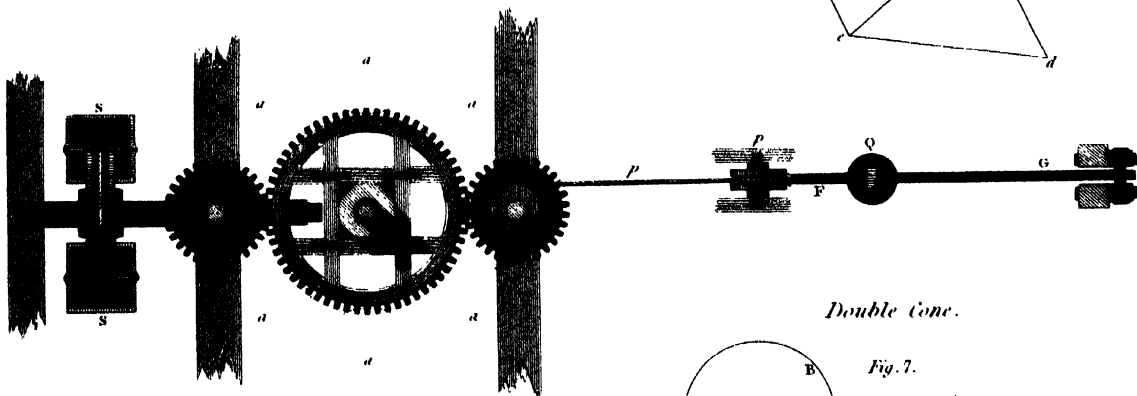


Fig. 2.

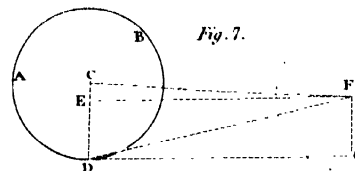


Plans.



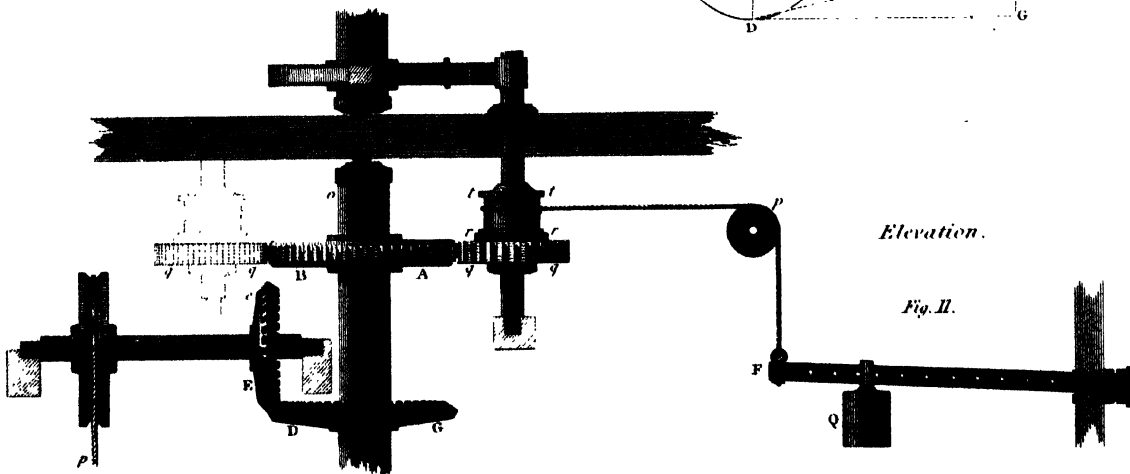
Double Cone.

Fig. 7.

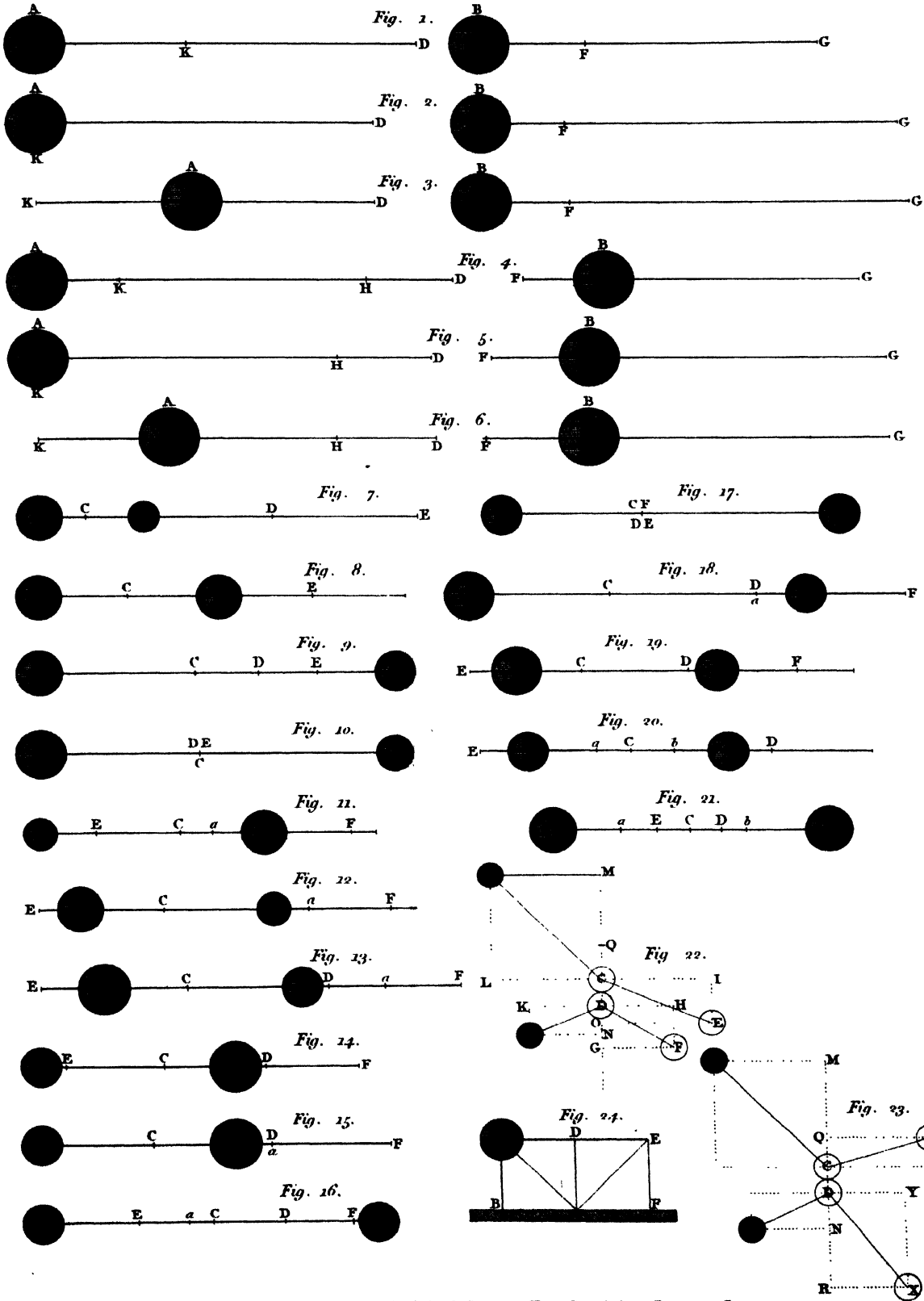


Elevation.

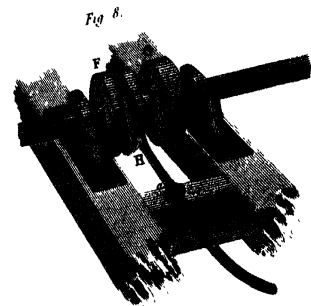
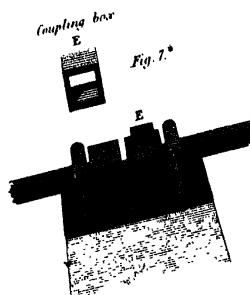
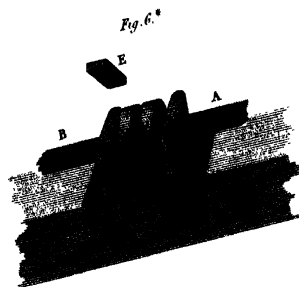
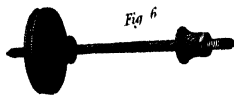
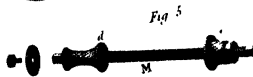
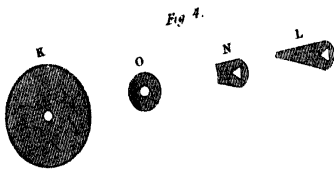
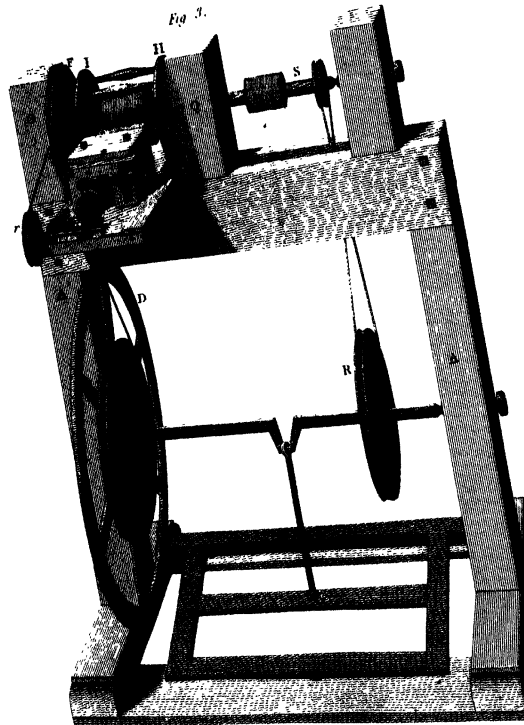
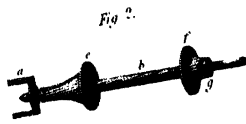
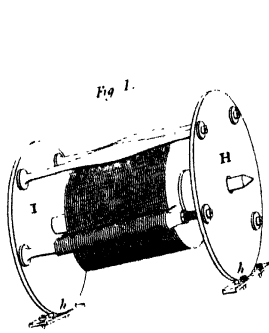
Fig. 11.



COLLISION.



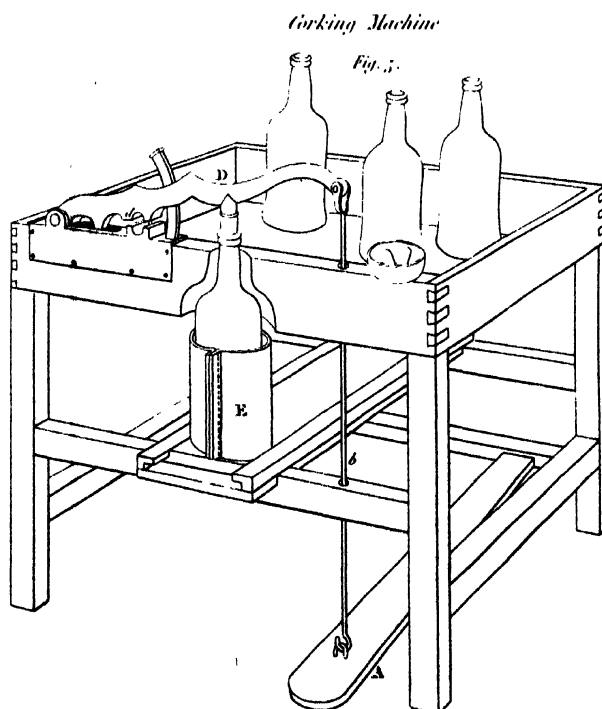
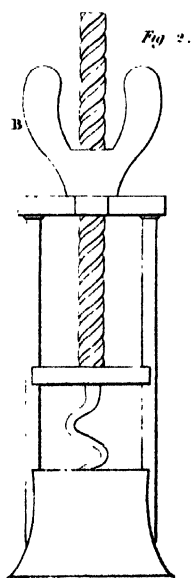
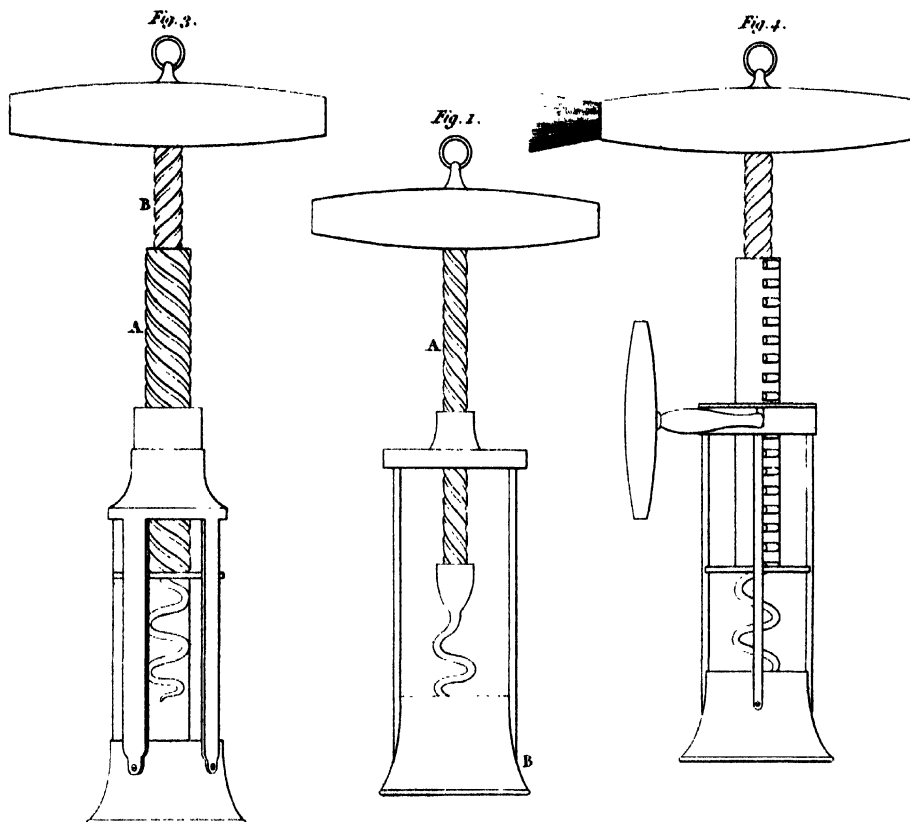
MECHANICS.
COMB MAKING.



Lowry sculp.

Published as the directors, 1815, by Longman, Hurst, Rees, Orme & Brown, Paternoster Row.

J. Perry Junr. delin.



MECHANICS

CRANES,

by M^r Ferguson.

PLATE XVIII.

Fig. 2.

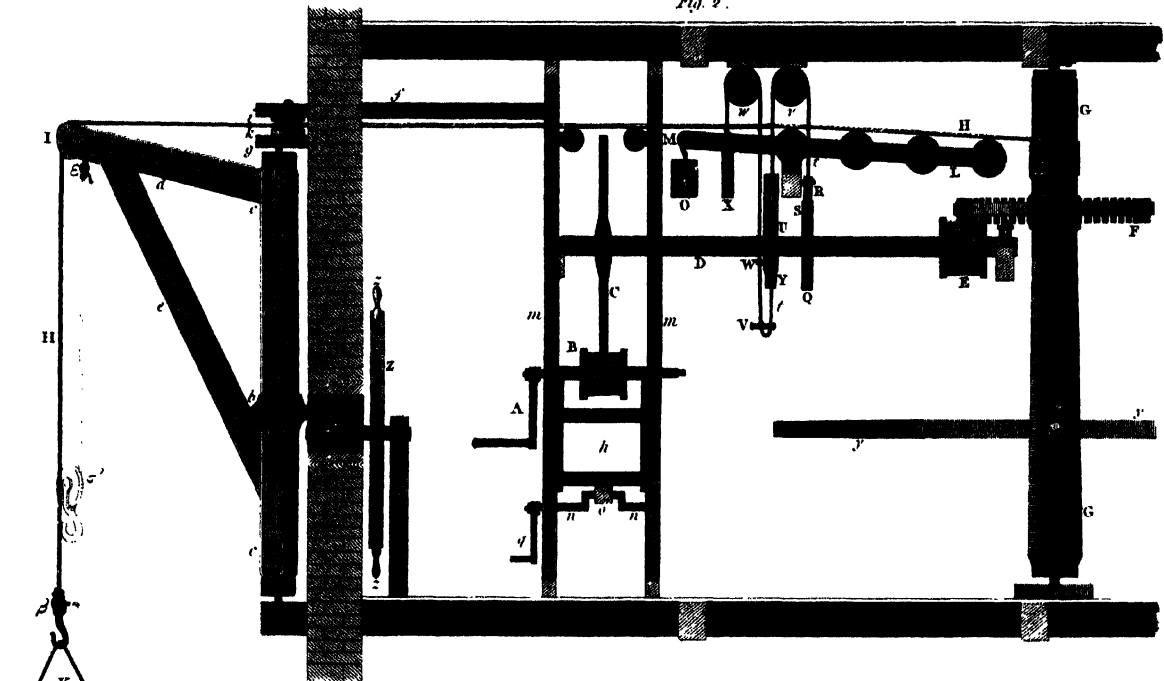
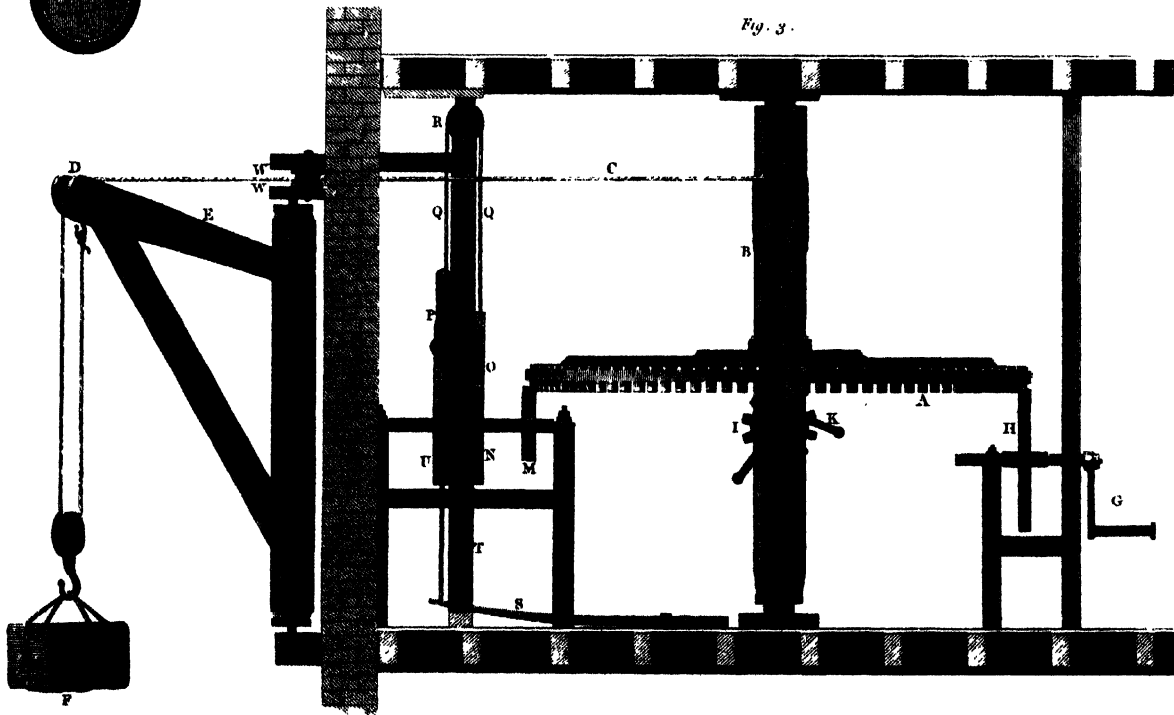
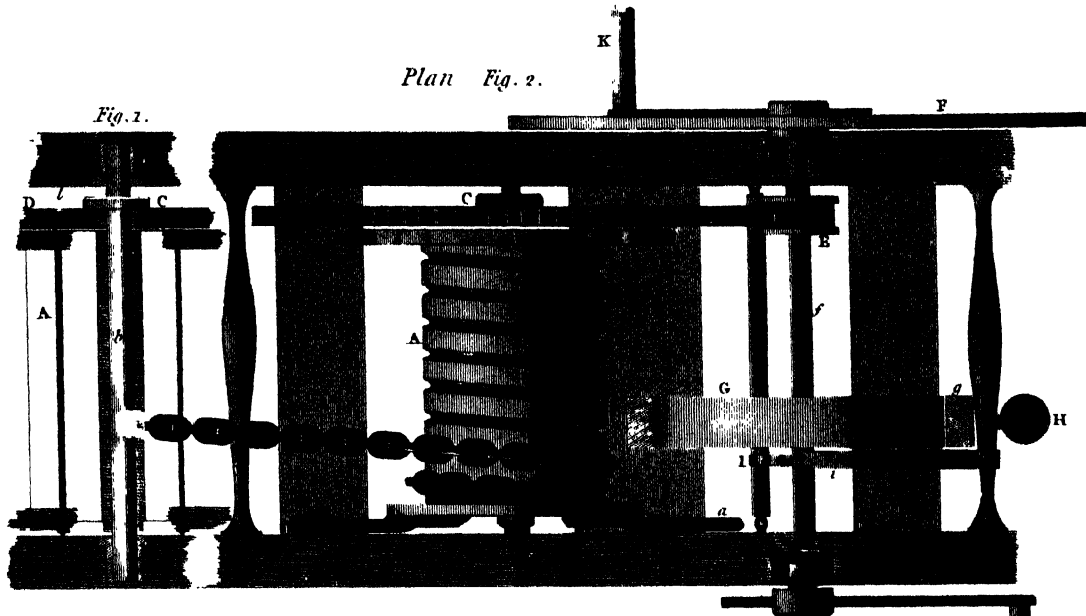
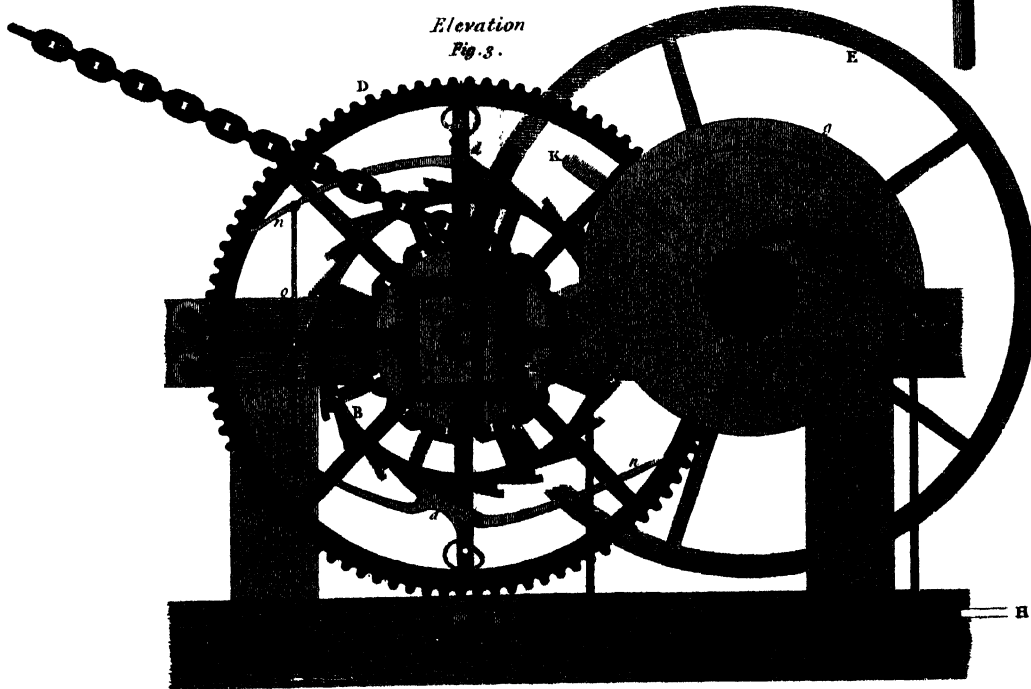


Fig. 3.





M^r SMEATON'S design for a CRANE, for the Wool Quay, Custom House, London. 1789.

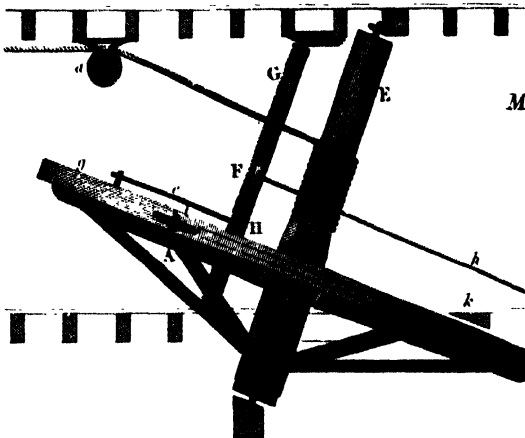


Scale of Inches.

20 40 60 80

Reduced by permission from the Original Drawing in the possession of Sir Joseph Banks K.B. by J. Rury Junior.

Fig. 1.



M^r WHITE'S
Crane.

Fig. 2.

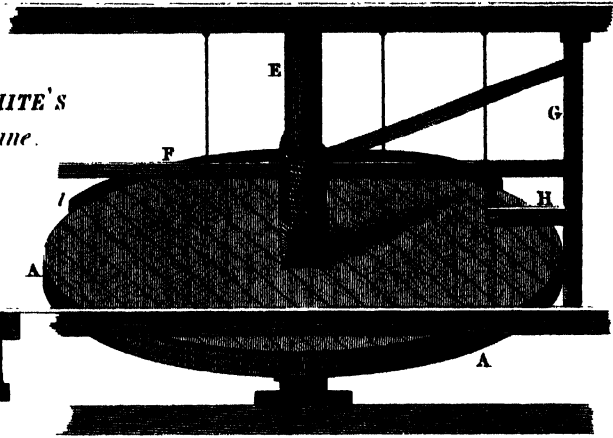
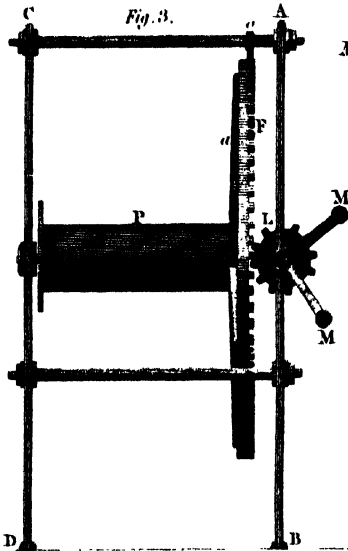
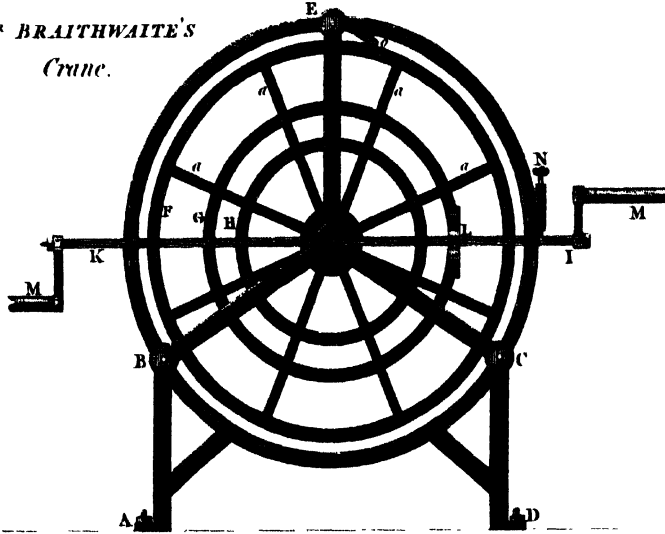


Fig. 3.



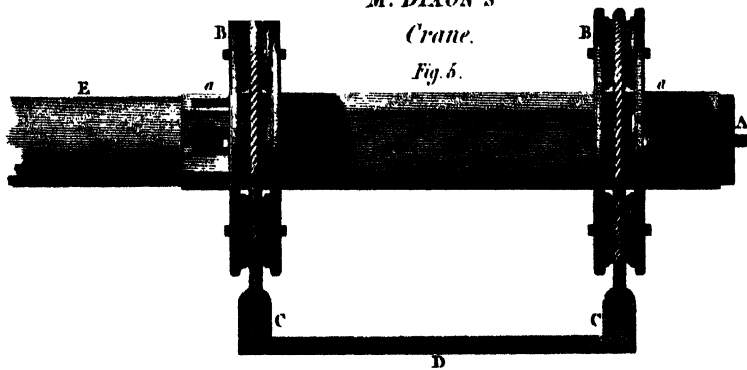
M^r BRAITHWAITE'S
Crane.

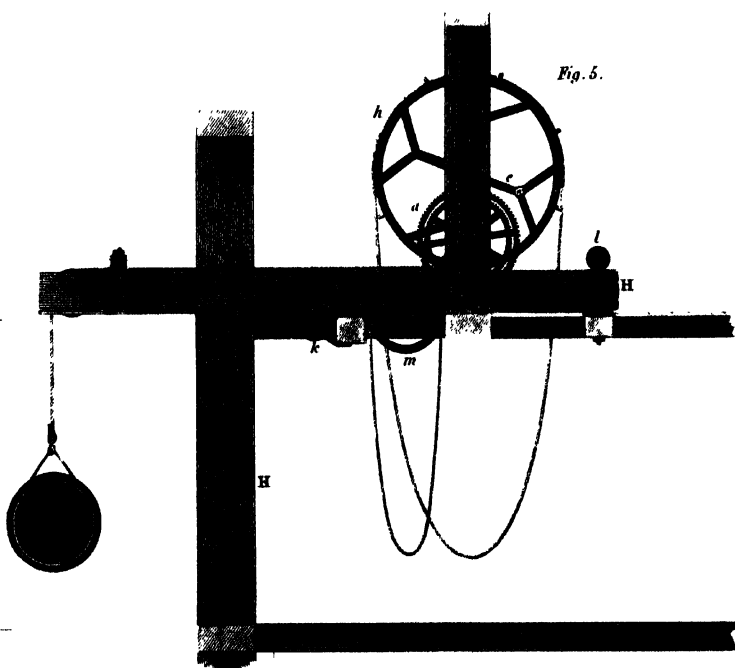
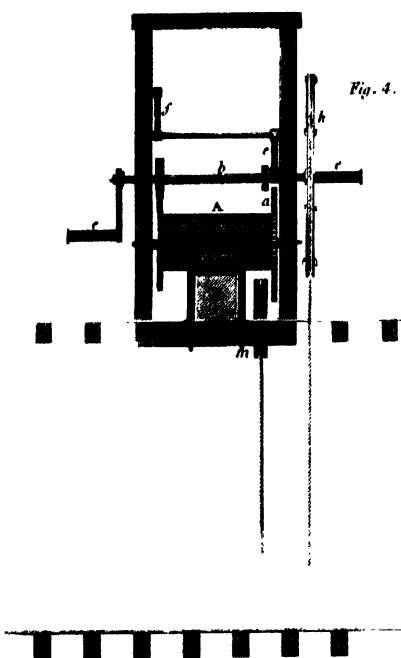
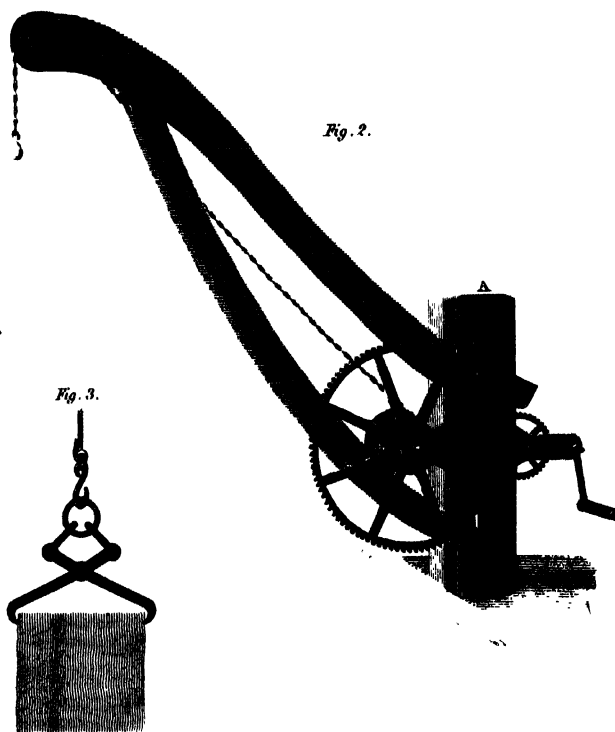
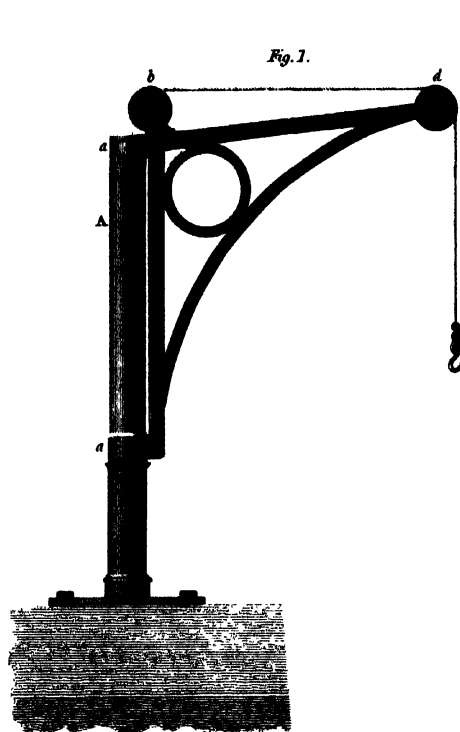
Fig. 4.



M^r DIXON'S
Crane.

Fig. 5.





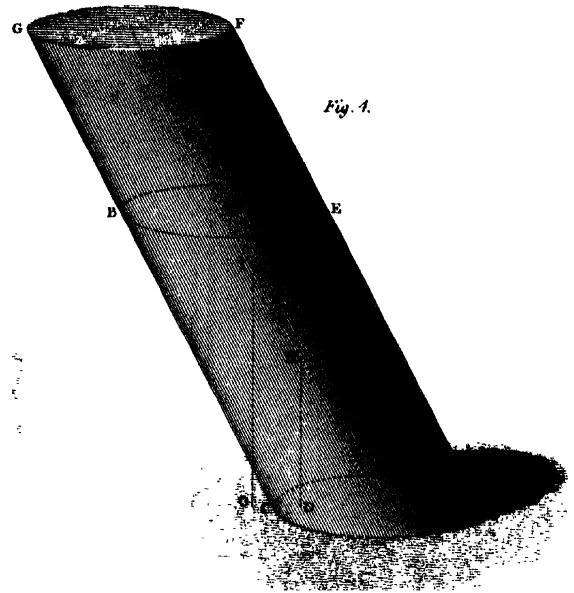
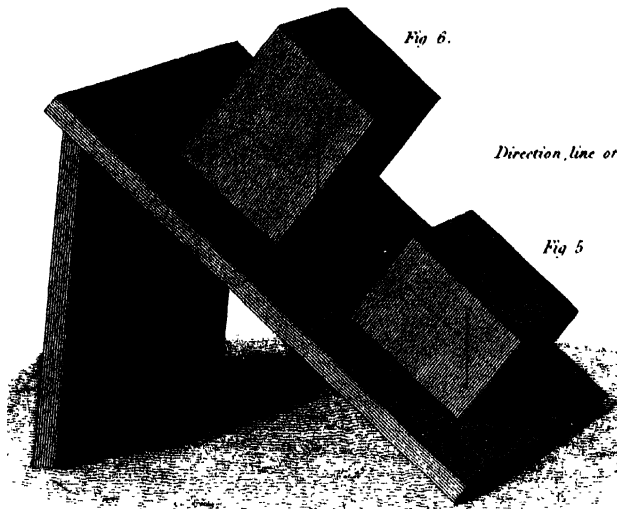
MECHANICS.

PLATE XXII & XXIII.

DIRECTION of Motion.

Fig. 3.

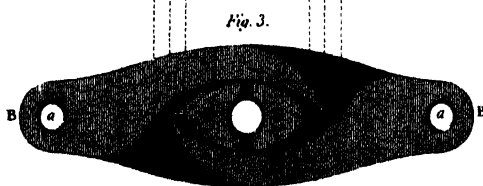
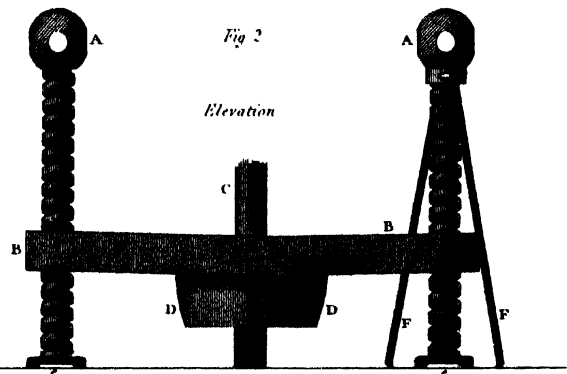
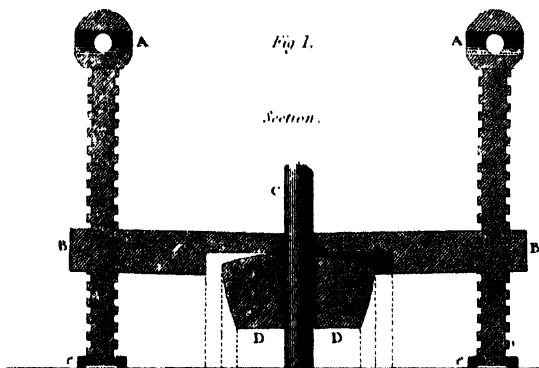
MA



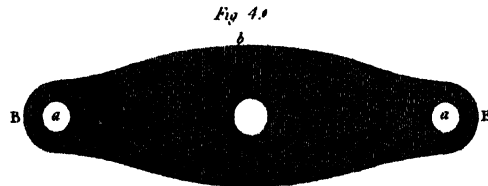
MECHANICS.

PLATE XXIII.

M^r Hill's Machine for DRAWING out Ships Bolts.



Plan of the lower Side.



Plan of the upper Side.

Machine for boring cylinders at the Falcon Iron Foundry, made by M. Dixon.

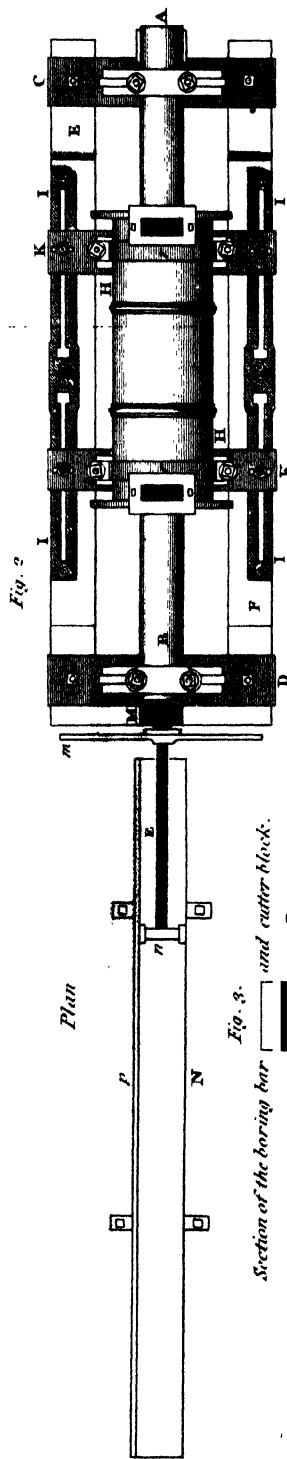
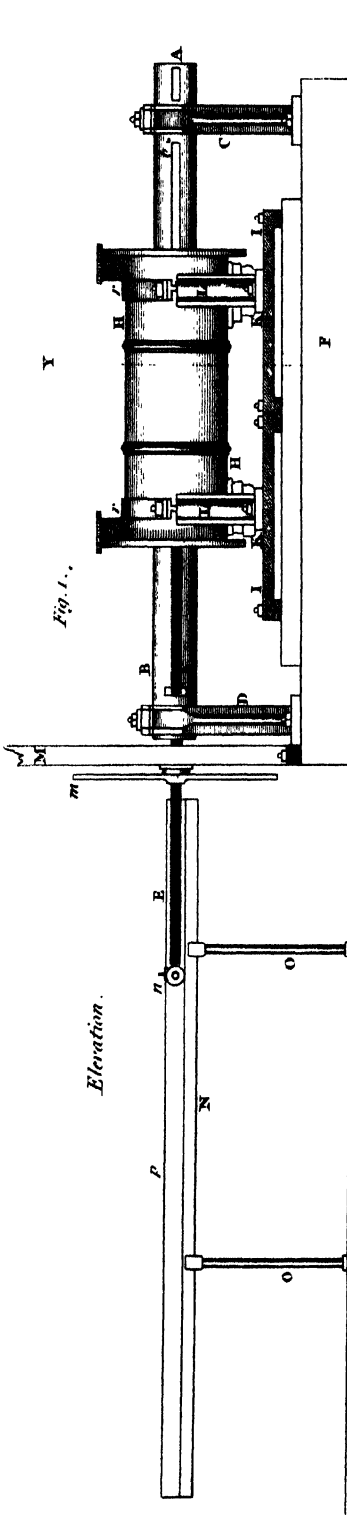
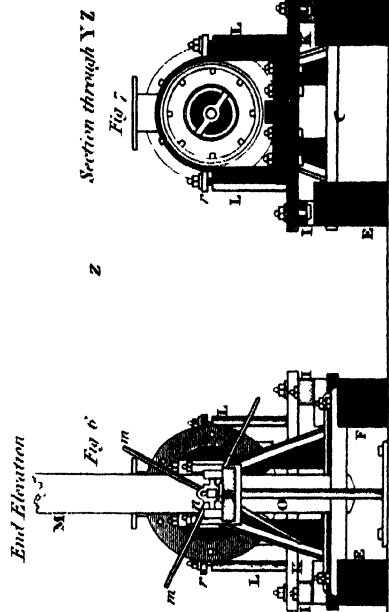
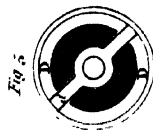
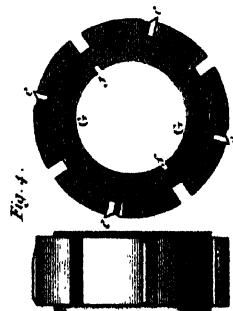
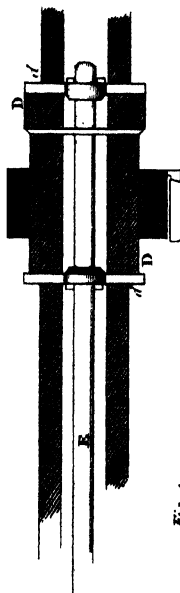
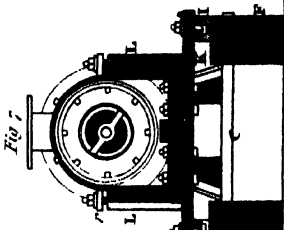


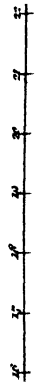
Fig. 3. Section of the boring bar and cutter block.



Section through YZ



Scale of Feet



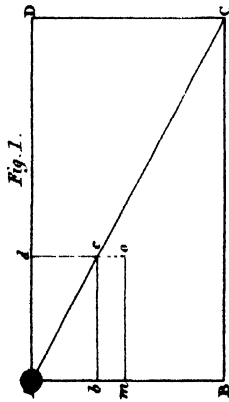


Fig. 1.

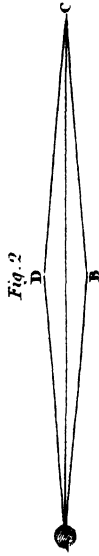


Fig. 2.

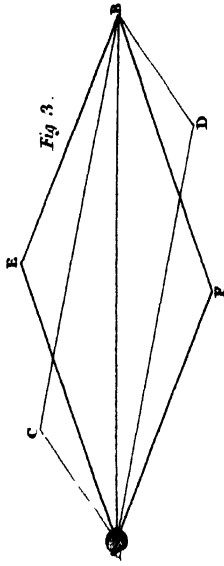


Fig. 3.

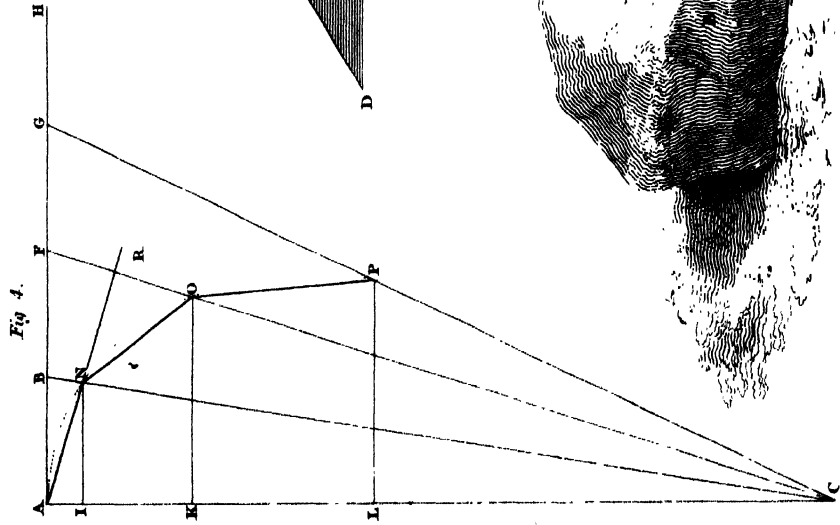


Fig. 4.

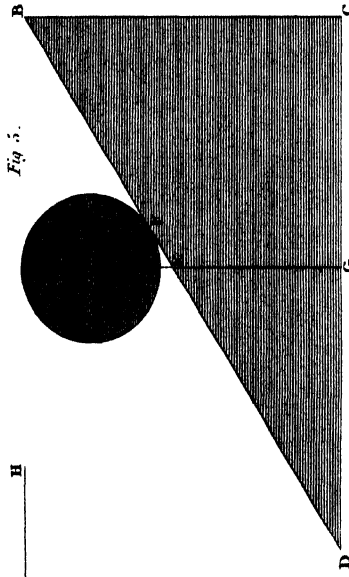


Fig. 5.

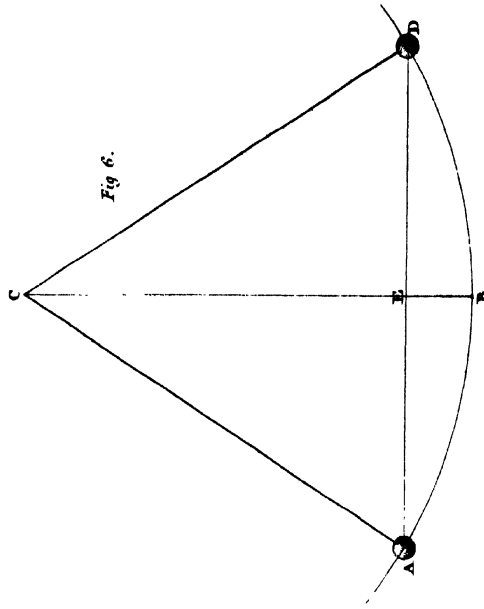


Fig. 6.

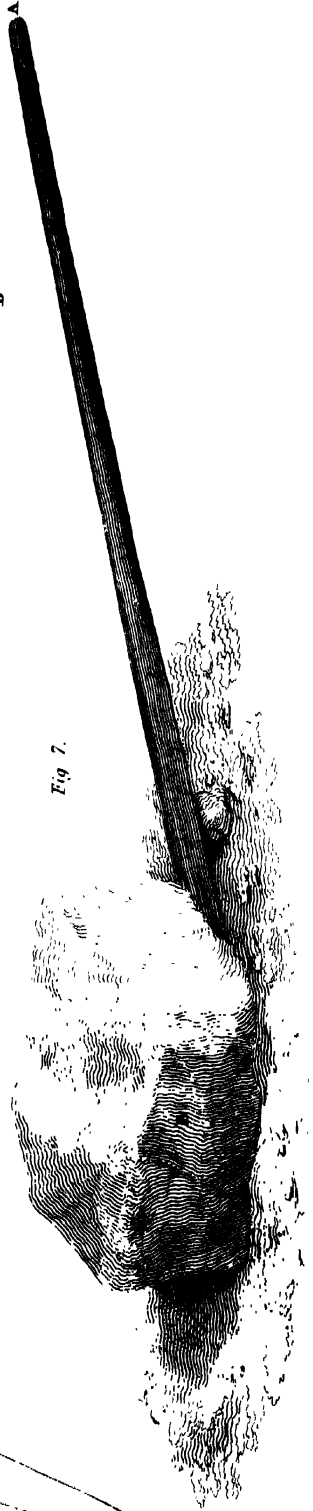


Fig. 7.

M E C H A N I C S .

D Y N A M O M E T E R S .

PLATE XXV

FOR MEASURING THE FORCE OF DRAUGHT.

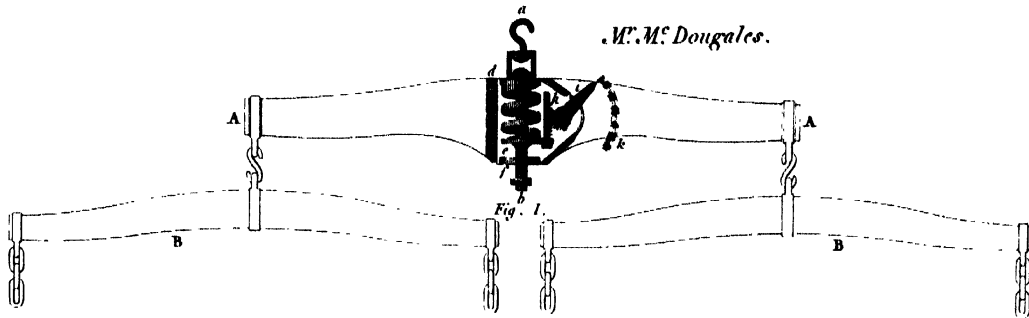


Fig. 3.

Mr. Salmons's contrivance for determining the force required to work a Mill.

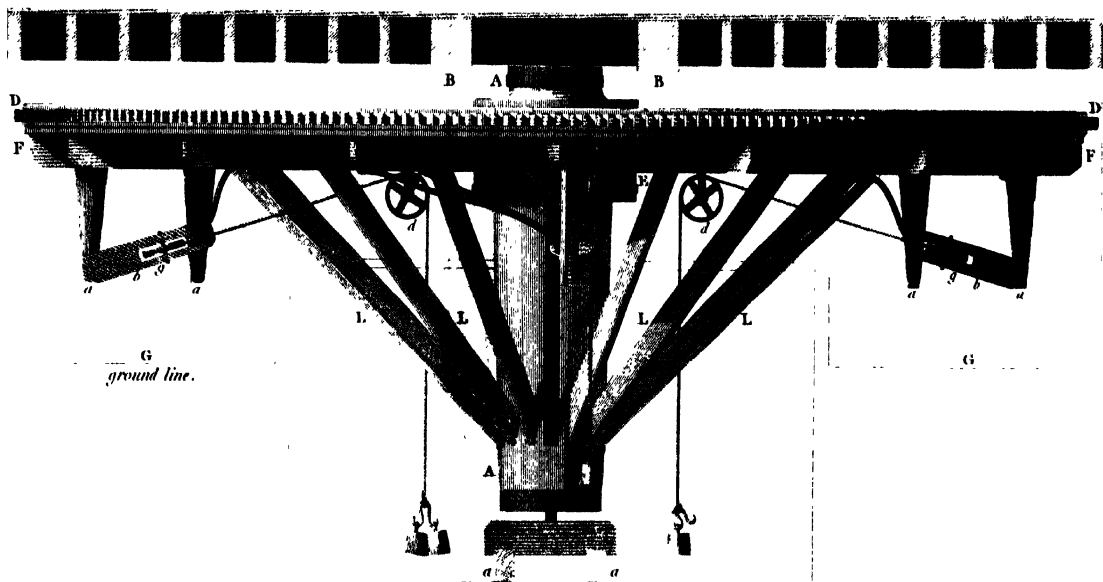
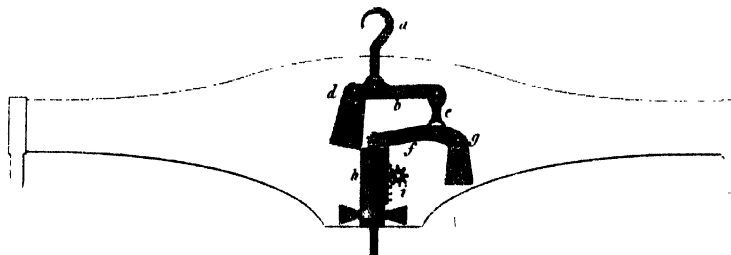


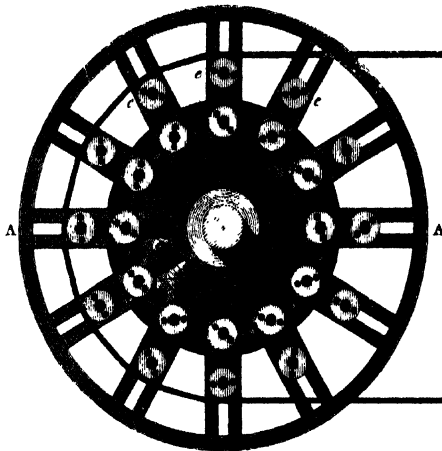
Fig. 2.

Mr. Salmons's Dynamometer.



EXPANDING RIGGERS.

Fig. 5.



M^r A. Flint.

Fig. 6.

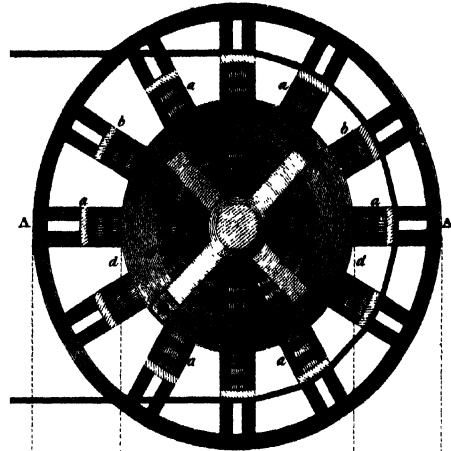


Fig. 10.

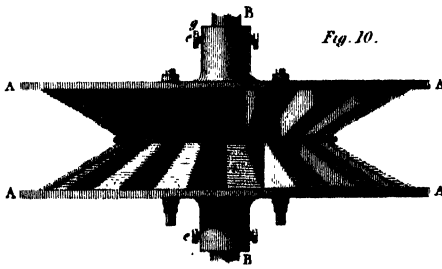


Fig. 7.

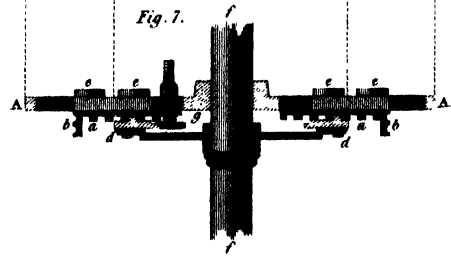


Fig. 11. M^r Farey's.

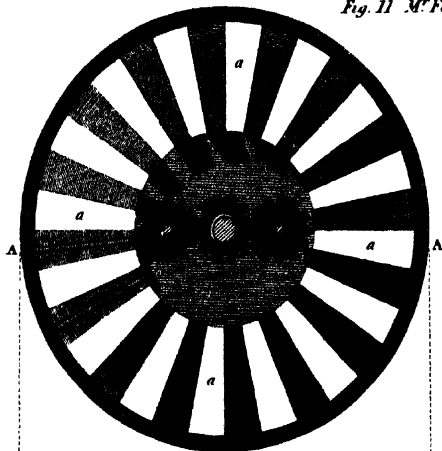


Fig. 8.

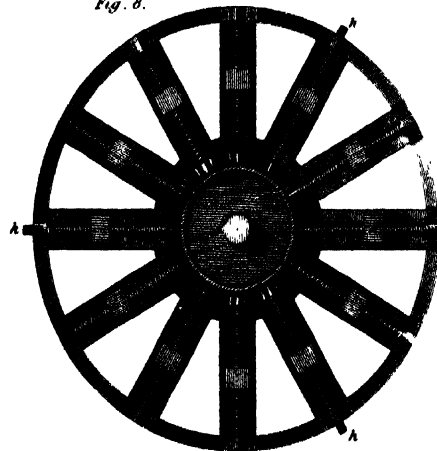


Fig. 12.

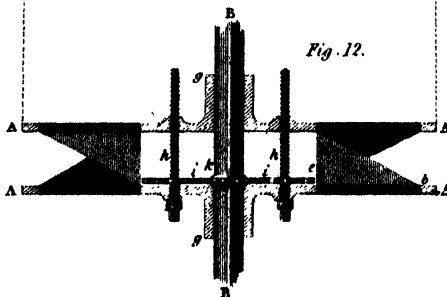
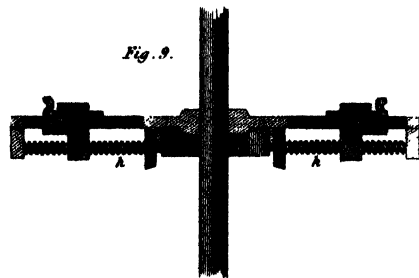


Fig. 9.



FLY-PRESS.

PLATE LXVII.

Fig. 1.

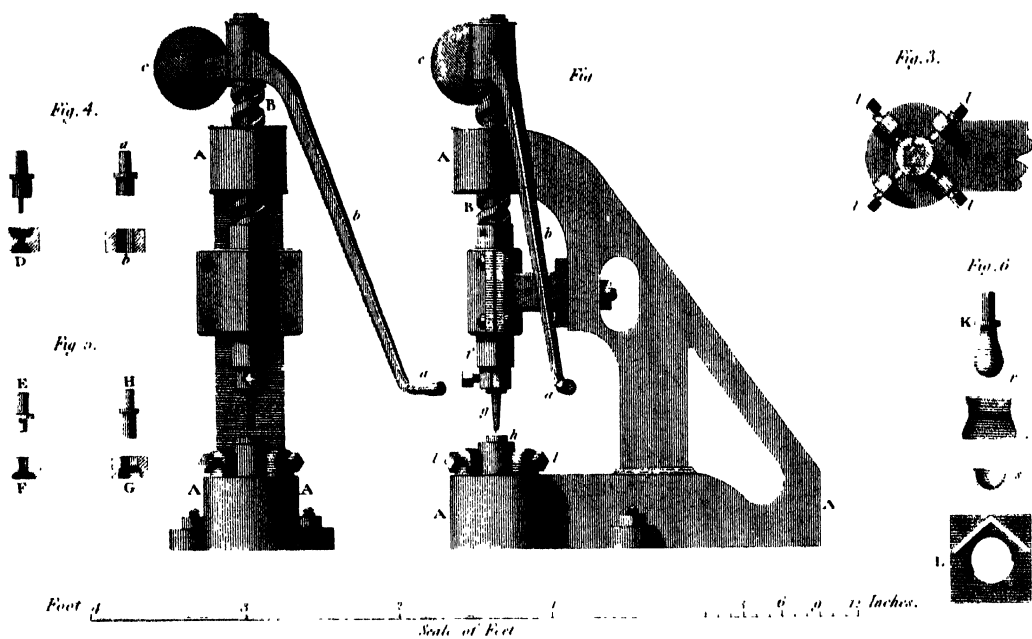
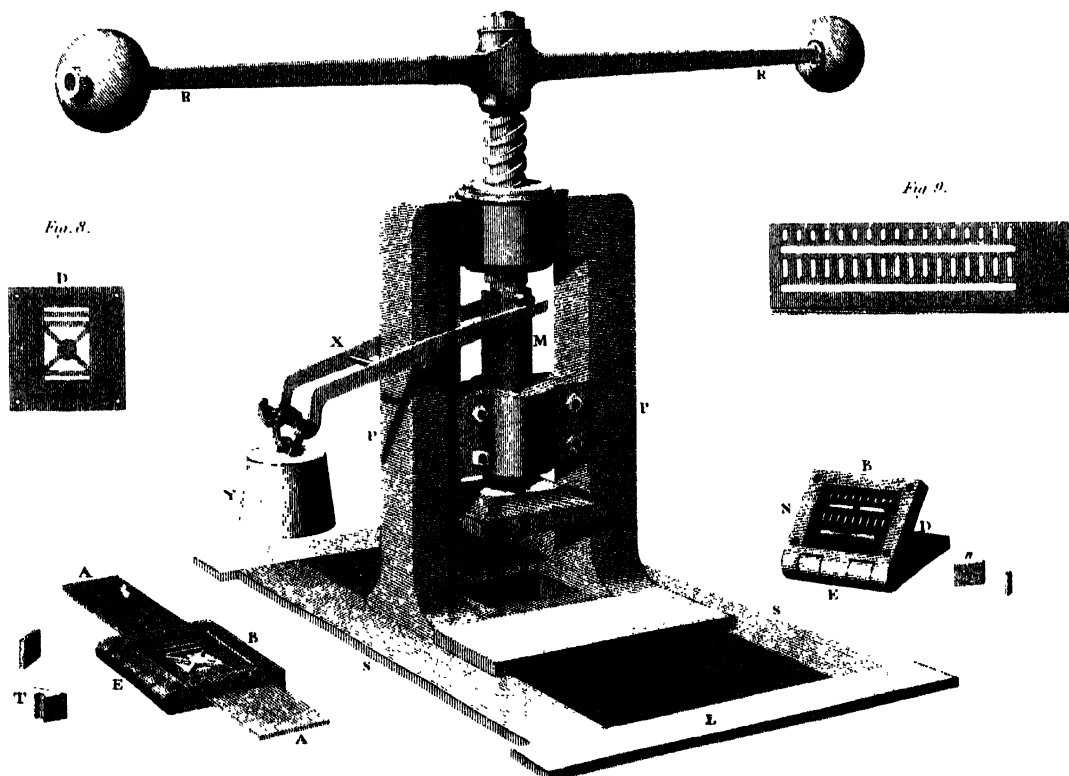
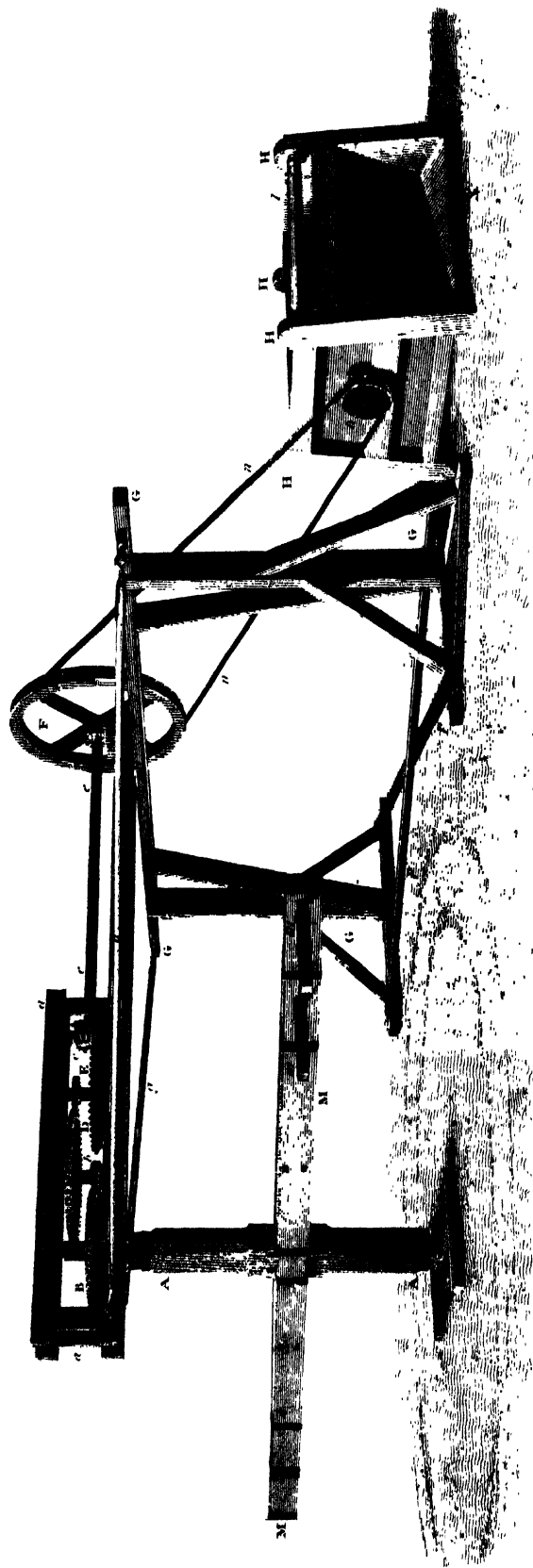


Fig. 7

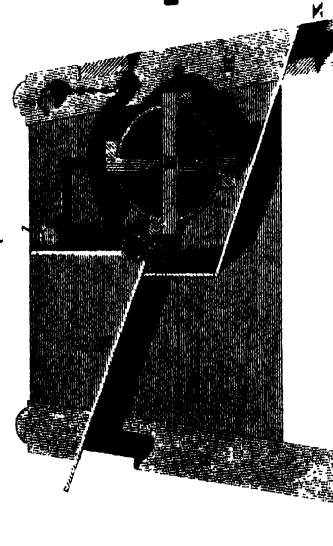


M^r R. SALMON'S, PORTABLE THRASHING MILL.

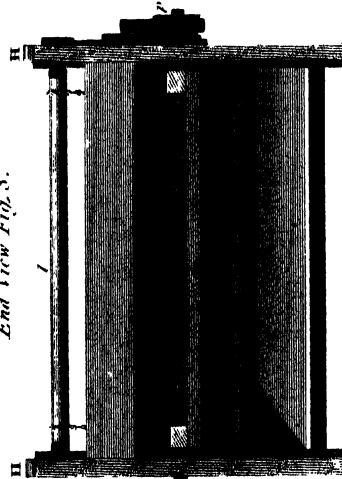
Perspective View Fig. 1.



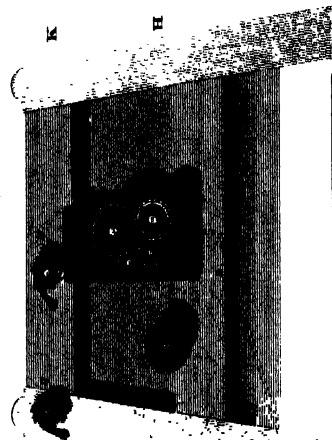
Section Fig. 2.



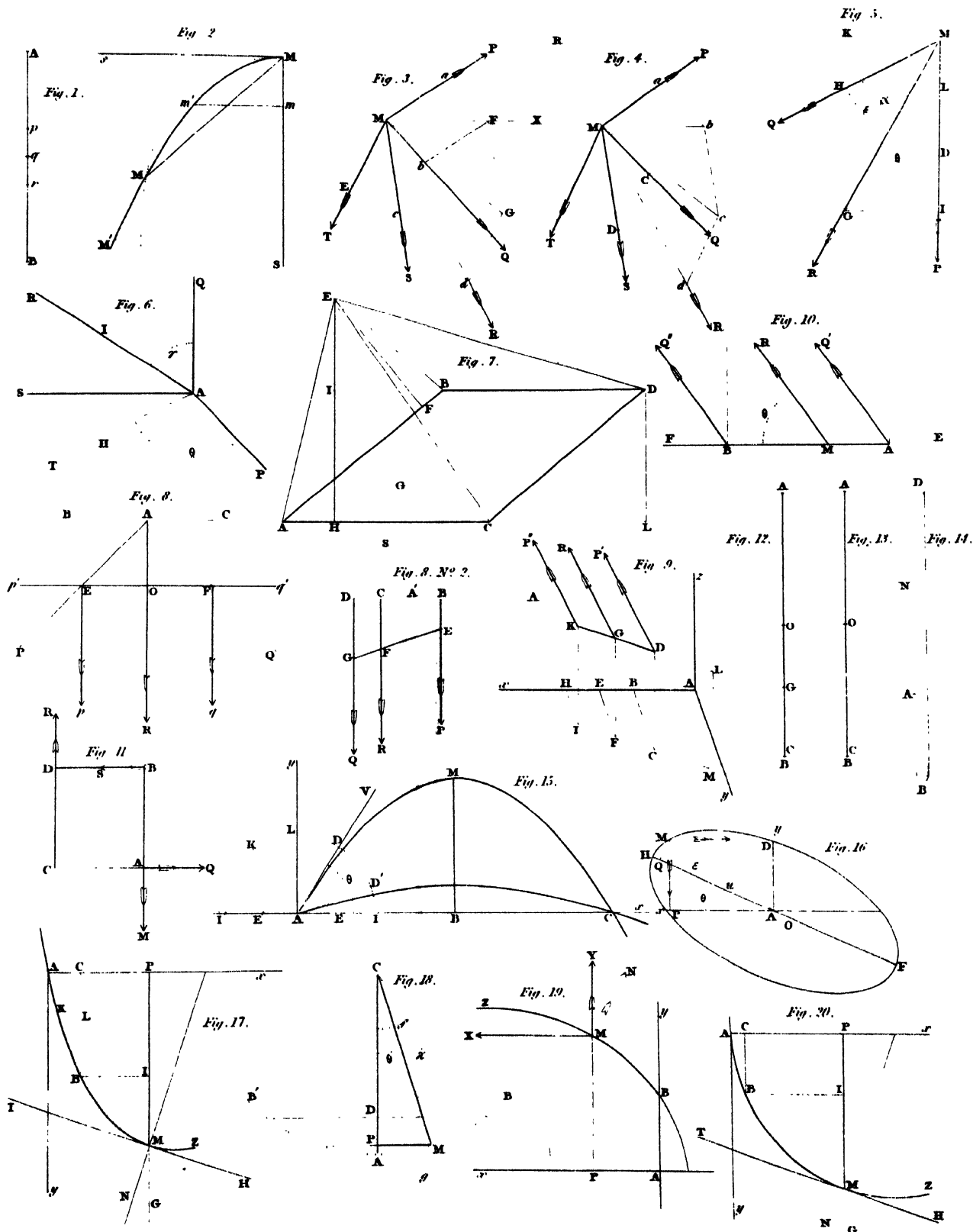
End View Fig. 3.



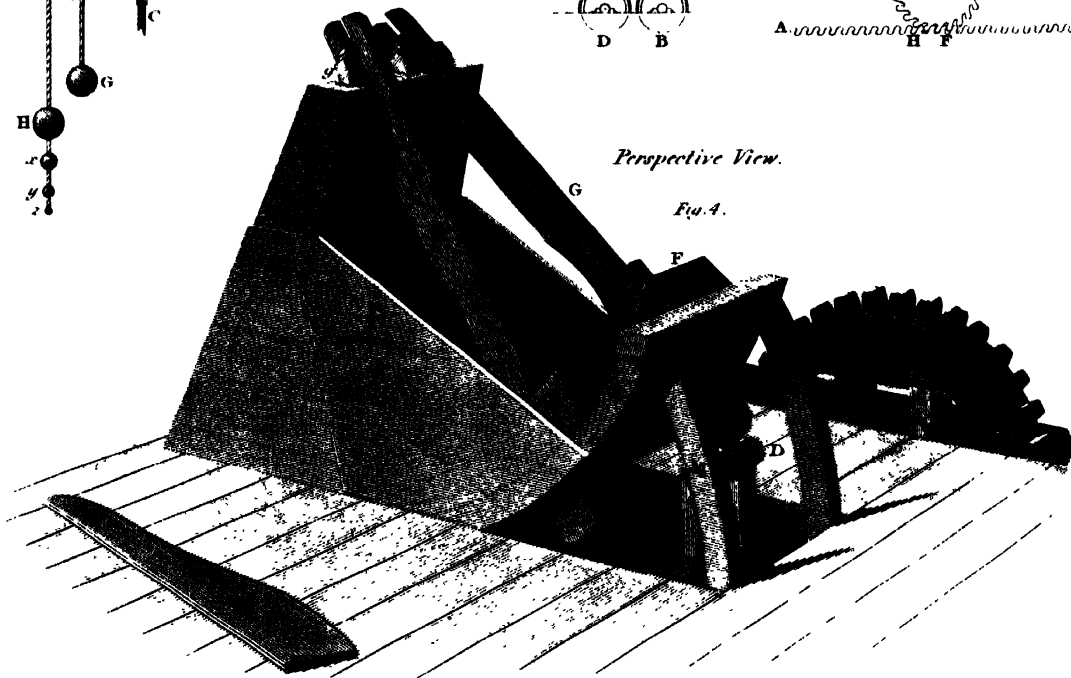
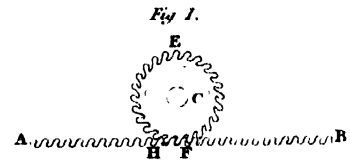
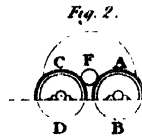
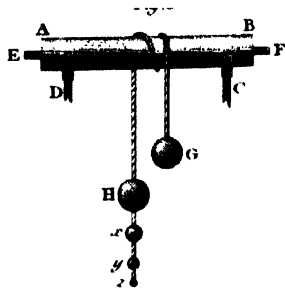
Elevation Fig. 4.



FORCE.



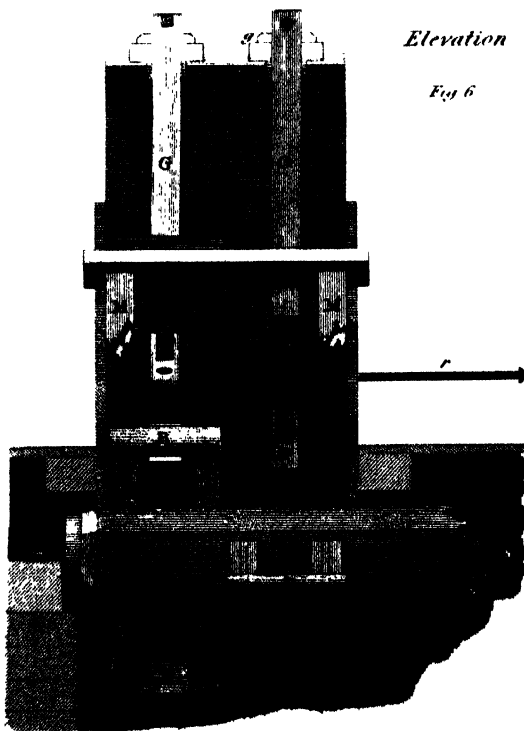
FRICTION AND FULLING MILL.



Perspective View.

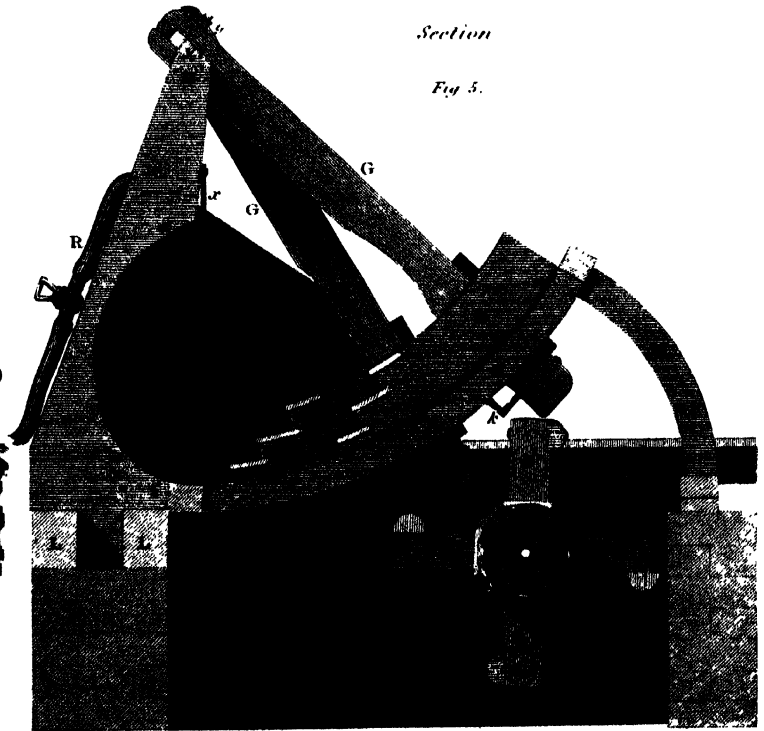
Fig. 4.

Note, these Stocks are for Scouring; for Milling cloth the trough and a is differently formed, see Weston



Elevation

Fig. 6.

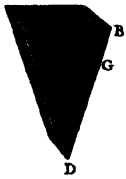


Section

Fig. 5.

MECHANICS

Fig. 1.



WEDGE.

Fig. 2



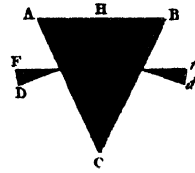
Fig. 3.



Fig. 4

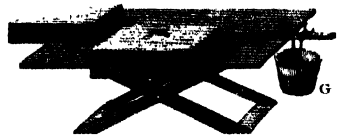


Fig. 5.



WEIGHT.

Fig. 6



WHEEL.

Fig. 8

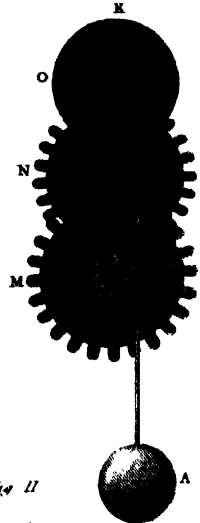


Fig. 7

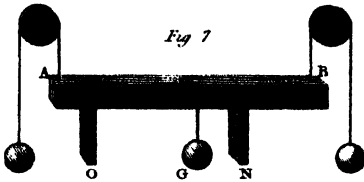


Fig. 9

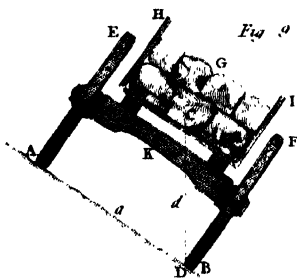


Fig. 10

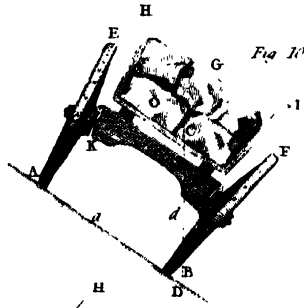


Fig. 11

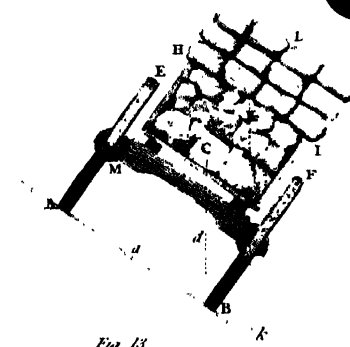


Fig. 12

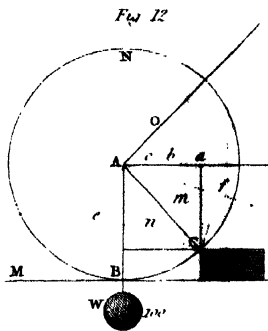


Fig. 13

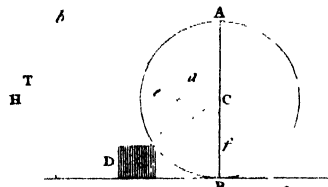
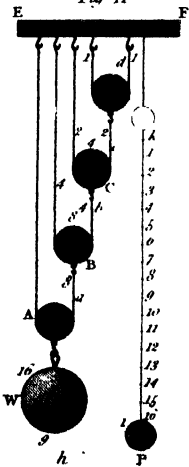


PLATE XLVI.

PLATE XLIV.

Fig. 14



Solid or least RESISTANCE.

Fig. 15

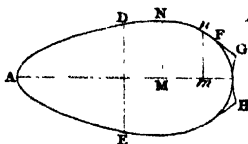
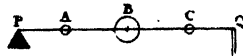


Fig. 16



REFRACTION

Fig. 17

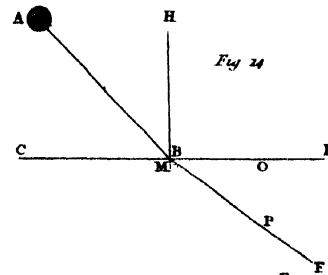


Fig. 18

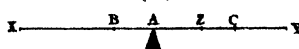
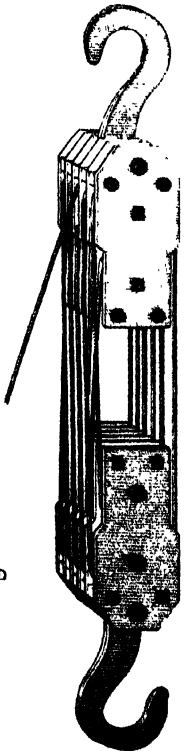
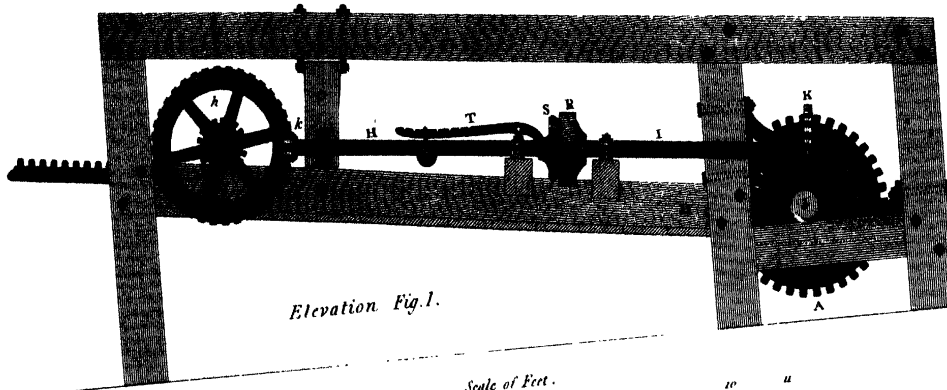


PLATE XLV.

Fig. 19

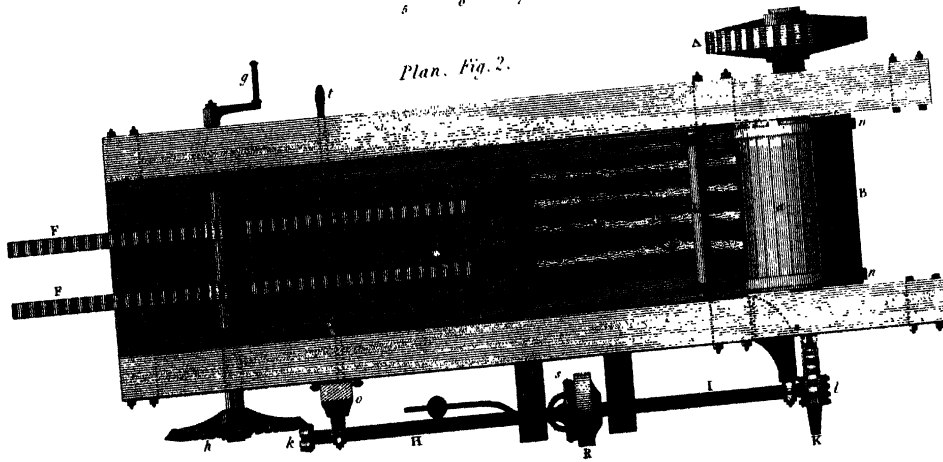


MECHANICS.
LOG-WOOD MILL.



Elevation Fig. 1.

Scale of Feet.
5 6 7



Plan Fig. 2.

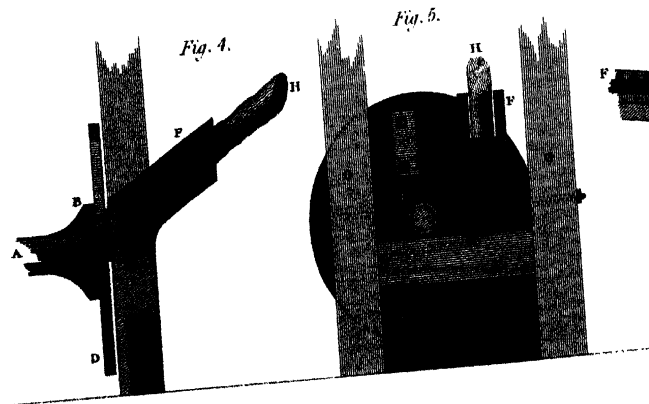


Fig. 4.

Fig. 5.

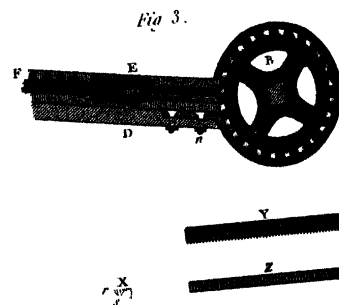


Fig. 3.

Lowry sculp.

MECHANICS

MECHANICAL POWERS &c.

PLATE XX.

Fig. 3.

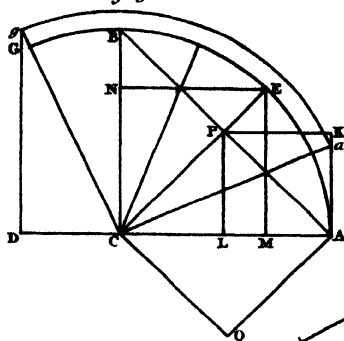


Fig. 2.

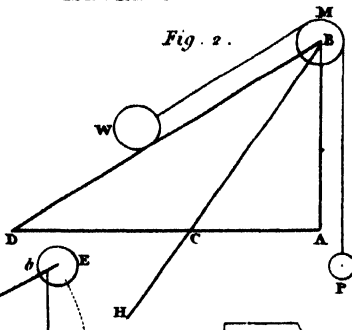


Fig. 1.

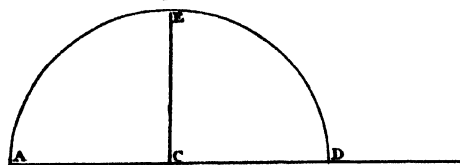


Fig. 6.

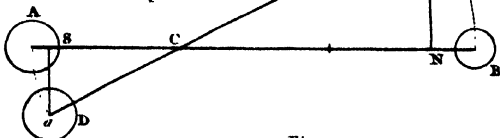


Fig. 7.

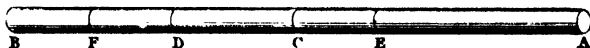


Fig. 8.

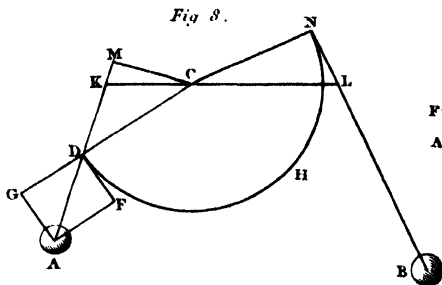


Fig. 9.

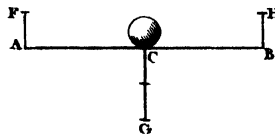


Fig. 10.

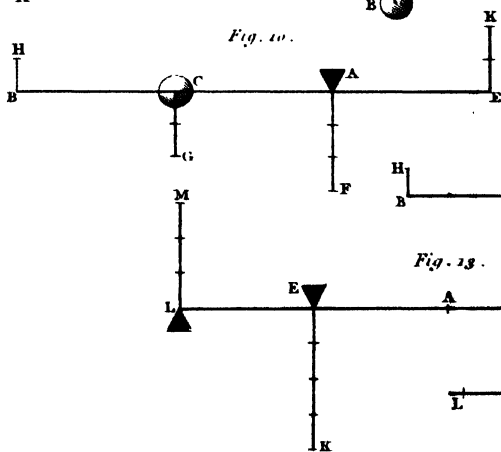


Fig. 11.

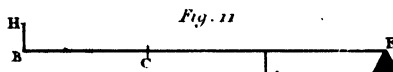


Fig. 13.

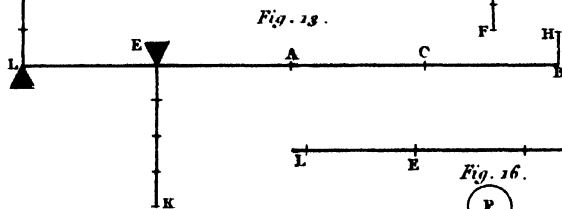


Fig. 12.

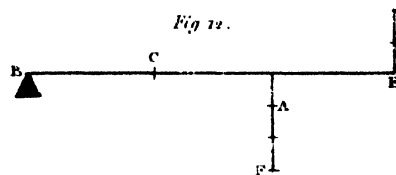


Fig. 14.

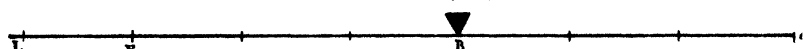


Fig. 16.

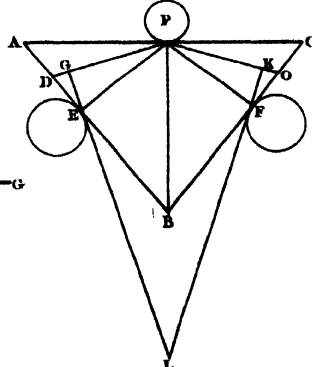


Fig. 17.

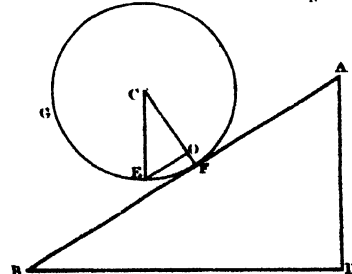


Fig. 15.

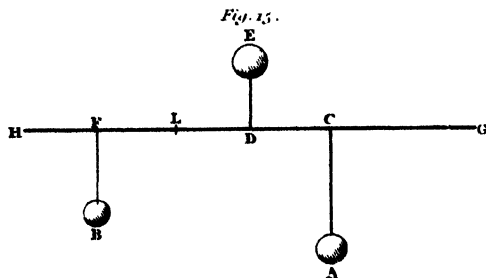


Fig. 1.

*View of a
Common Breast Mill.*

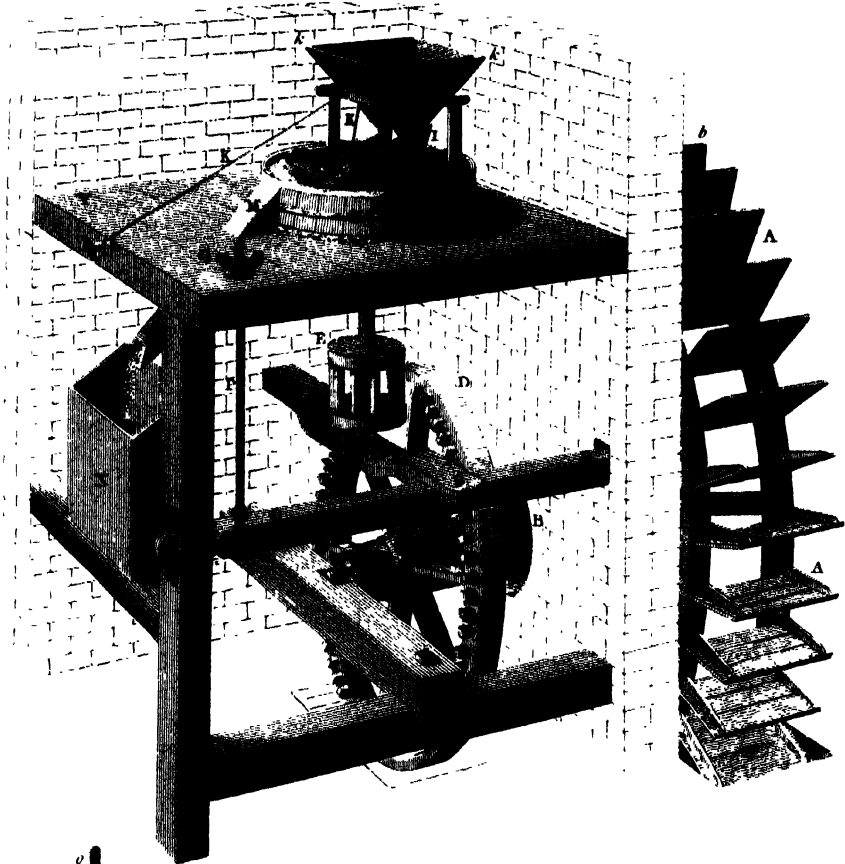
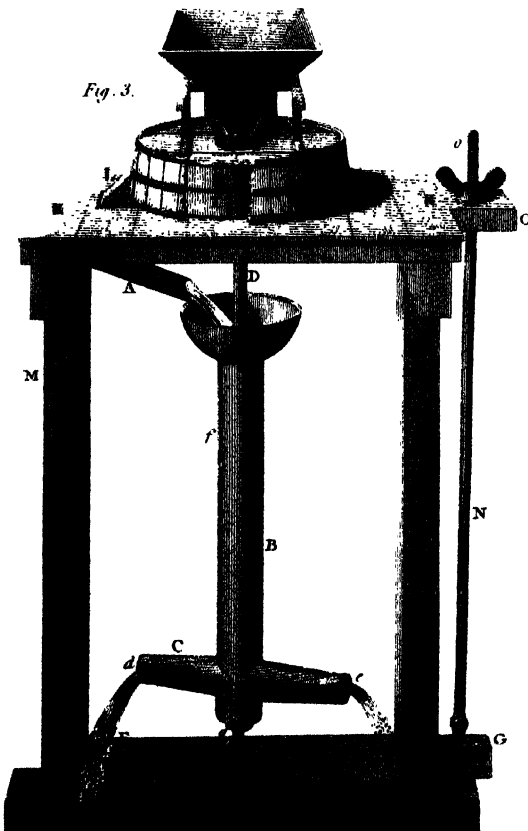


Fig. 2.



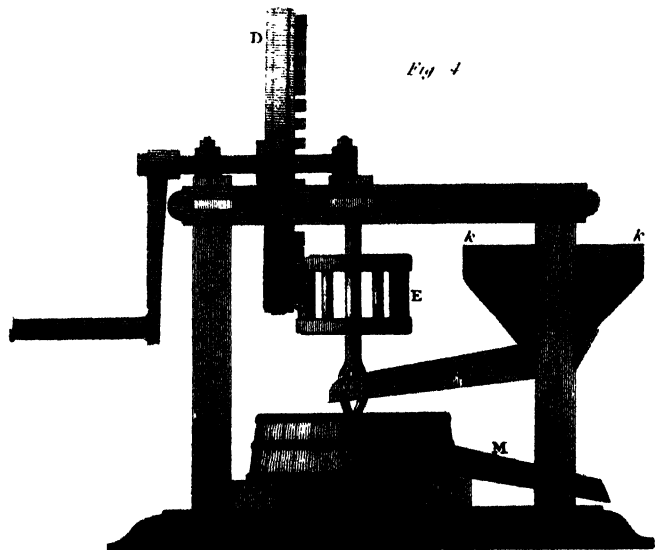
D' Burkes Mill.

Fig. 3.

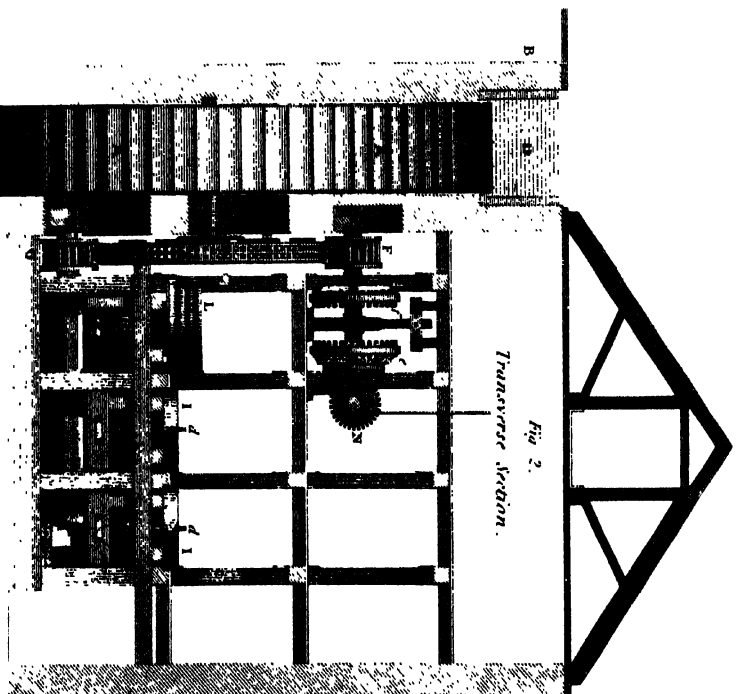
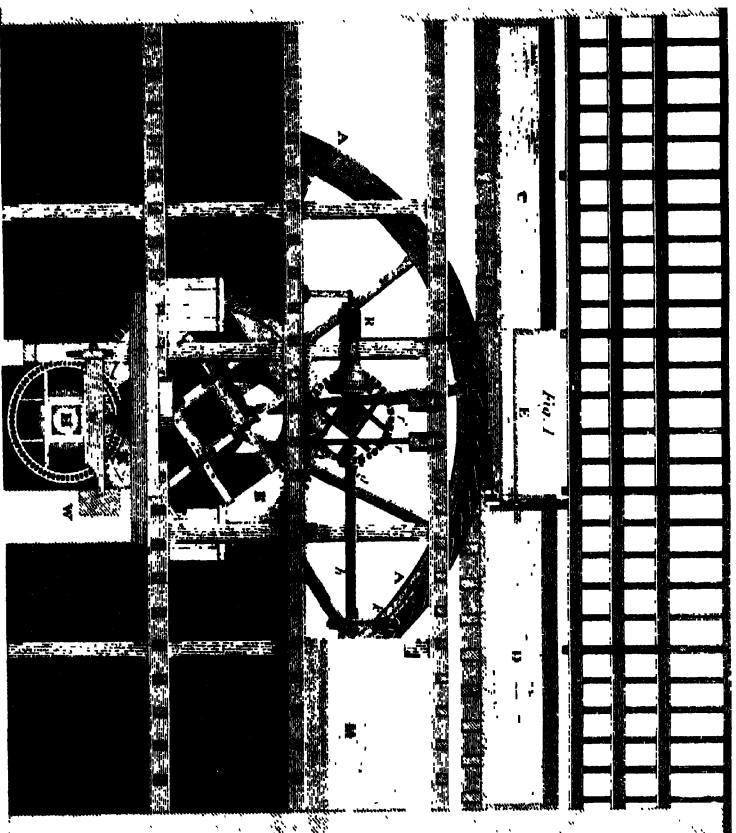


Portable or Hand Mill

Fig. 4



Designed by J. SMEDLEY, F.R.S. 1781.



Feet.

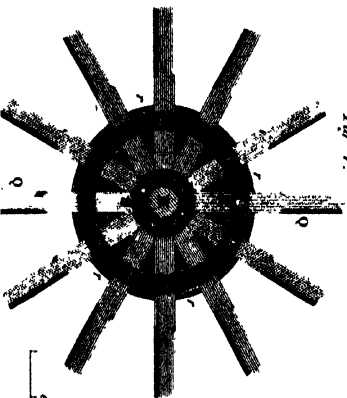
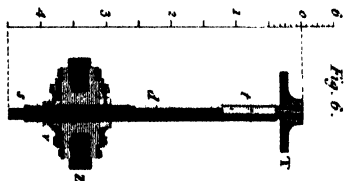
Fig. 1.



Fig. 8.



Fig. 4.



Cast Iron Axis.

Fig. 3.

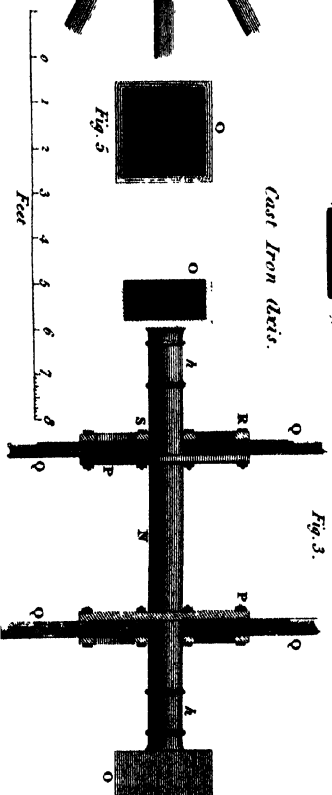


Fig. 5.



Feet.

MECHANICS.

PLATE XXXIV.

MOTION.&c.

Fig. 1.

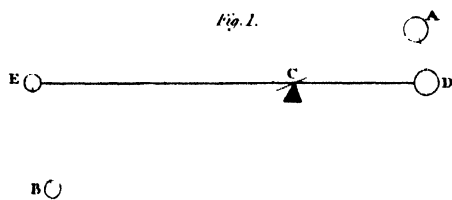


Fig. 2.

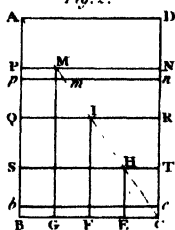


Fig. 3.

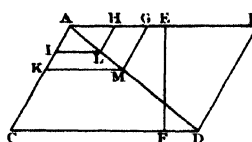


Fig. 4.

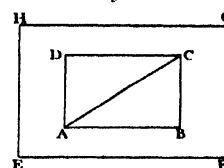
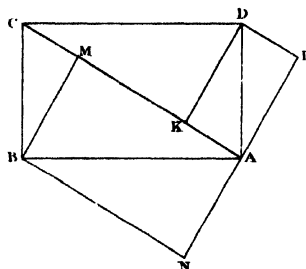


Fig. 7.



l'ia *ò.*

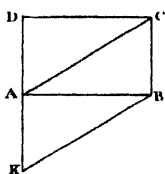


Fig. 6.

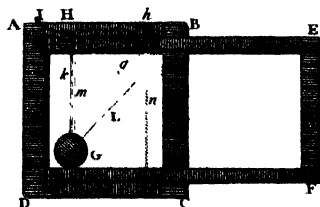


Fig. 8.

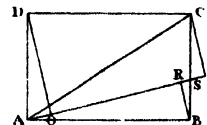


Fig. 9.

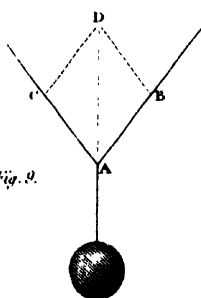
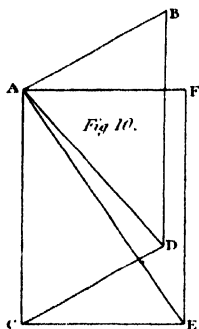
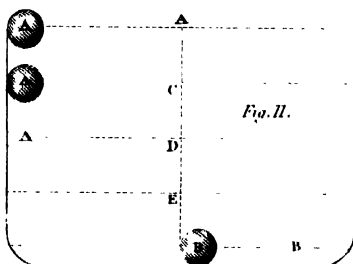


Fig 10.



Perpetual MOTION

Fig. 11.



PERCUSSION

Fig. 12.

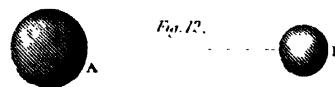


Fig. 13.

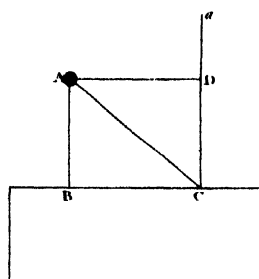
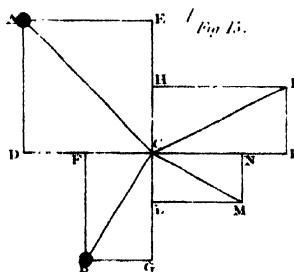


Fig. 14.



Fig. 15.



Inclined PLANE.

Fig. 16

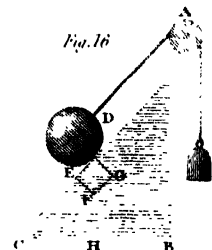


Fig. 17.

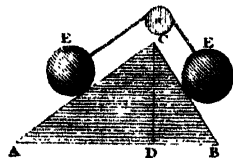


Fig. 18.

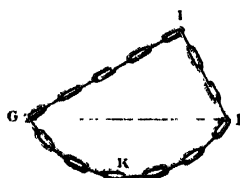


Fig. 19.

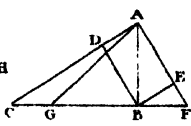


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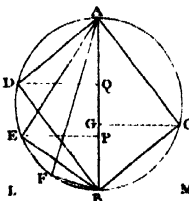
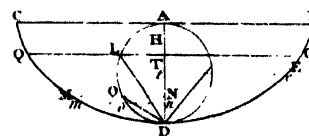


Fig. 21.



DRILLS.

Fig. 1.



Fig. 2.

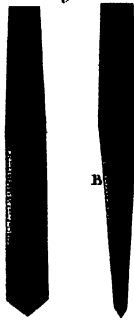


Fig. 3.



Fig. 4.

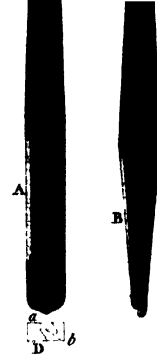


Fig. 5.



Fig. 6.



Fig. 7.

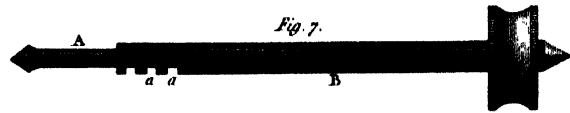


Fig. 8.

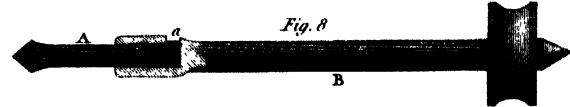


Fig. 9.



DRILLING MACHINES.

Fig. 10.

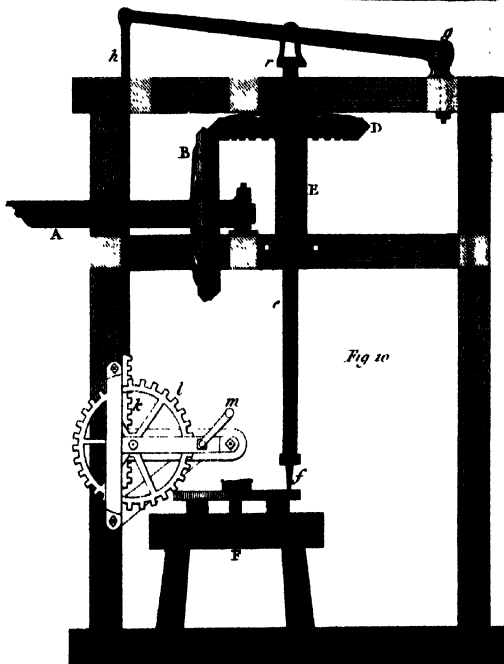
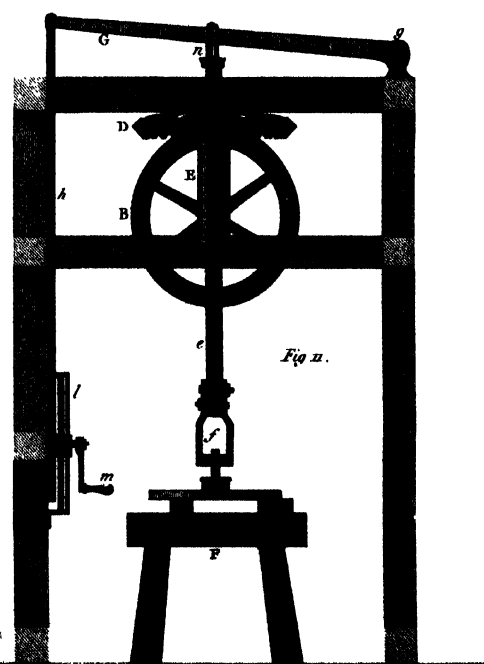
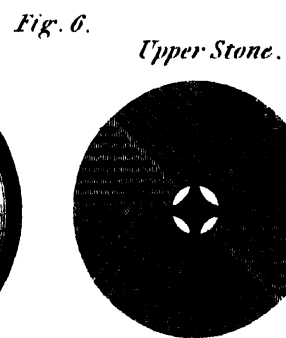
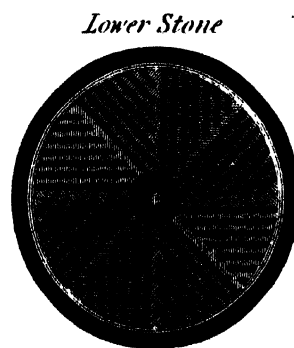
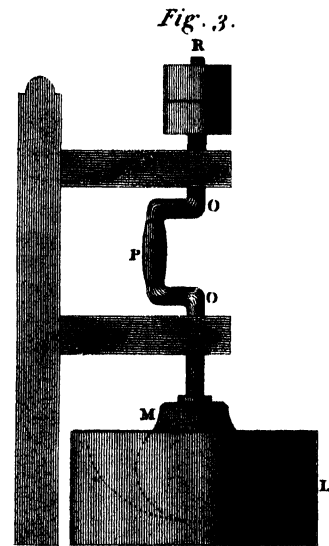
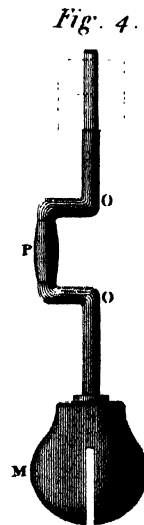
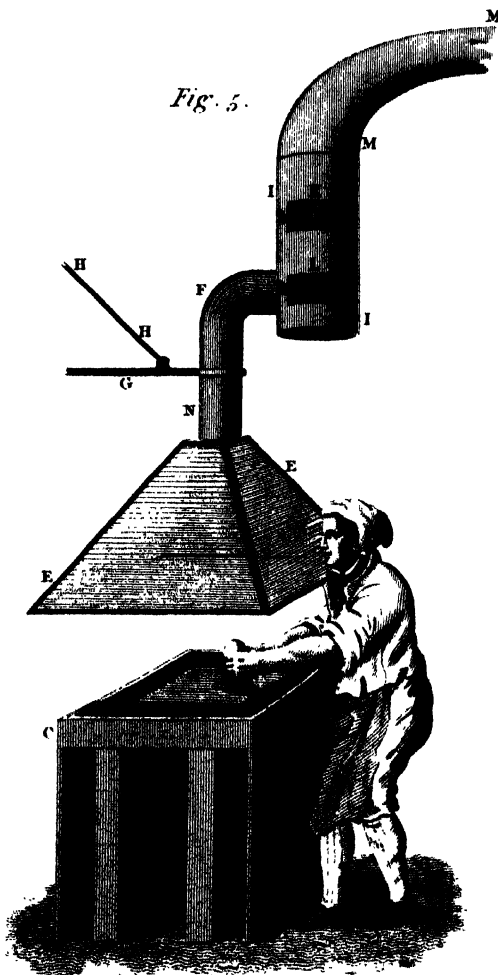
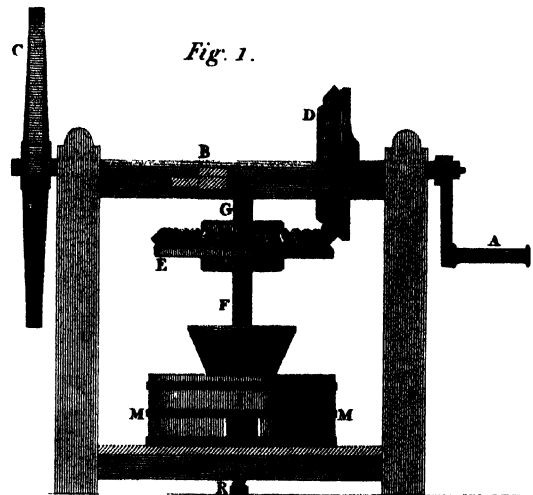
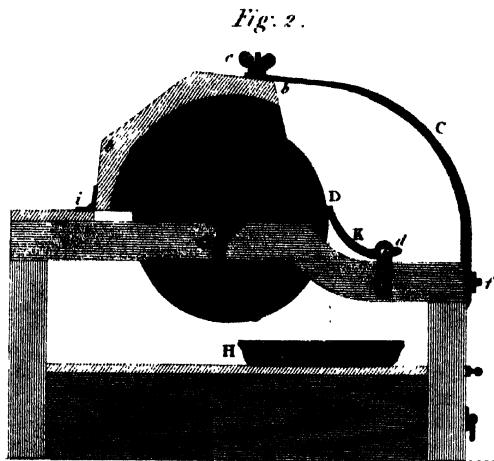


Fig. 11.

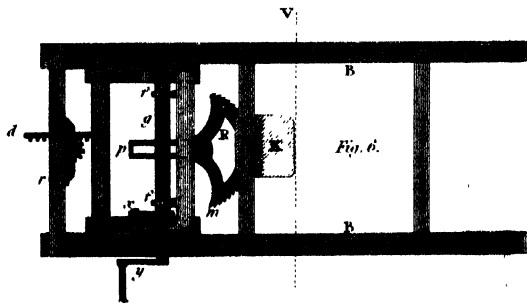
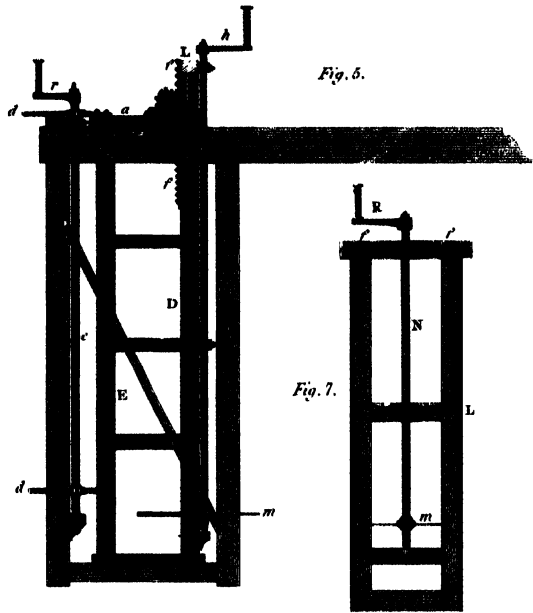


COLOUR MILL.

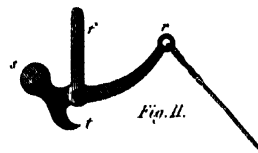
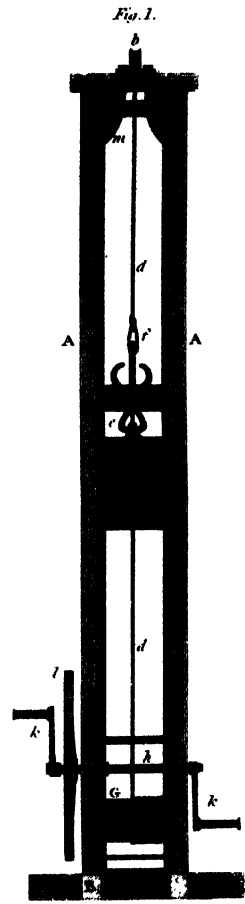
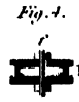
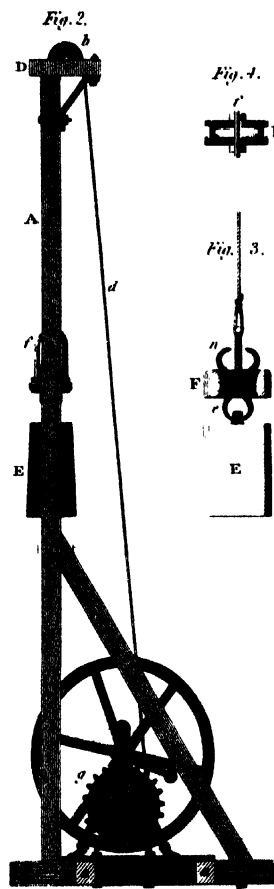
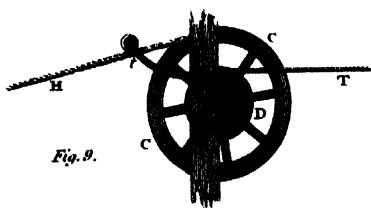
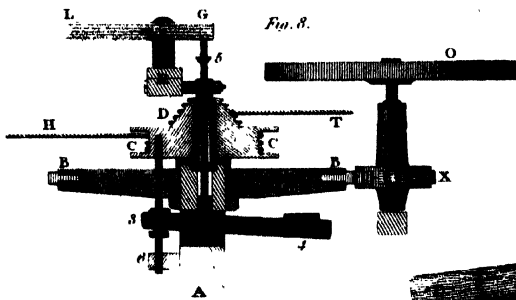


MECHANICS. PILE DRIVING MACHINE.

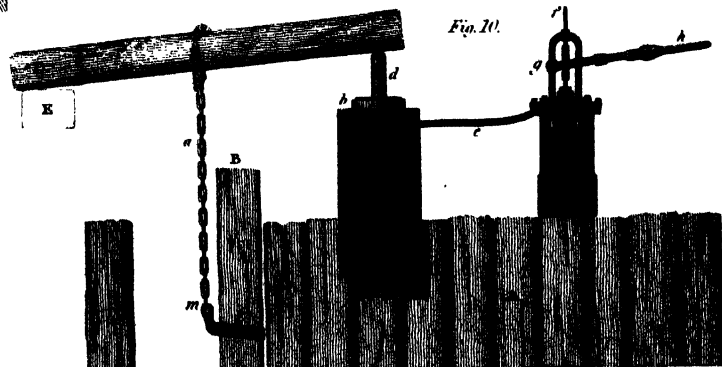
PLATE XXIV.



Section of Valow's Pile Engine.



M^r Bramah's Machine for Drawing Piles out of the Ground.



ROTATION.

Fig. 1.

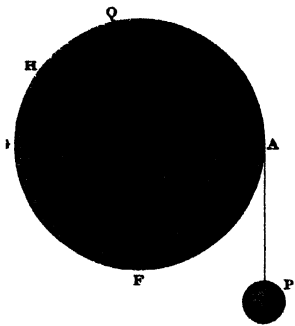


Fig. 2.

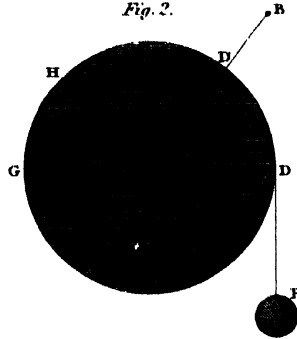


Fig. 3.

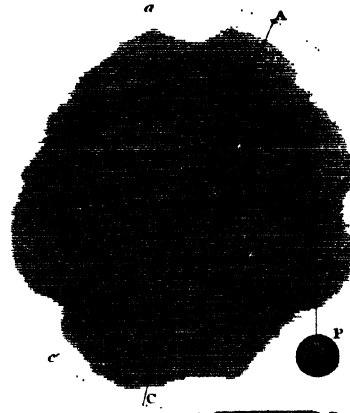


Fig. 4.

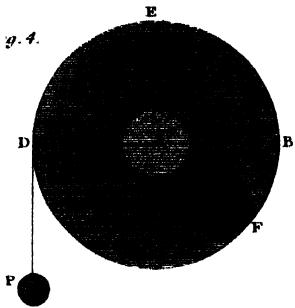


Fig. 5.

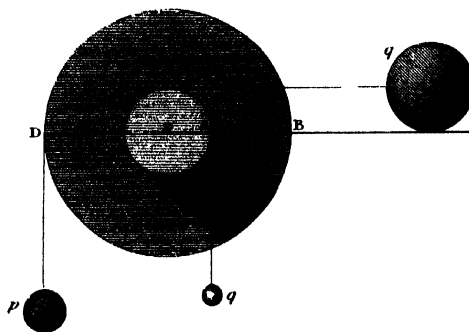


Fig. 6.

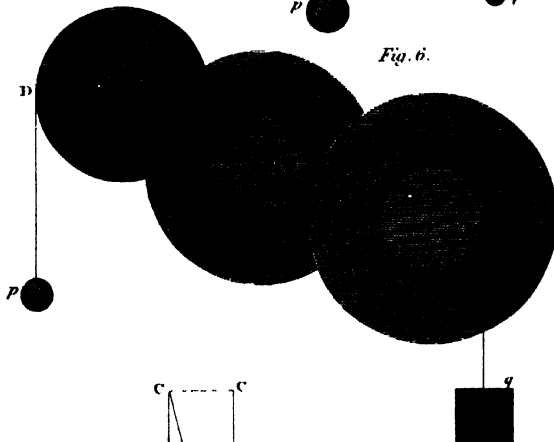
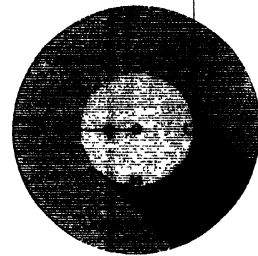


Fig. 7.

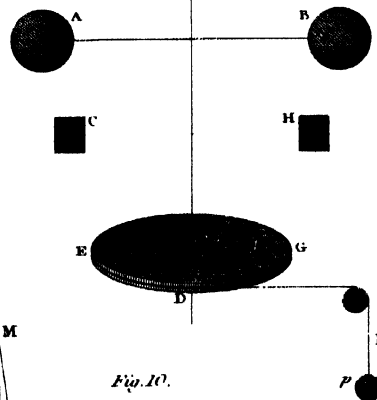


Fig. 8.

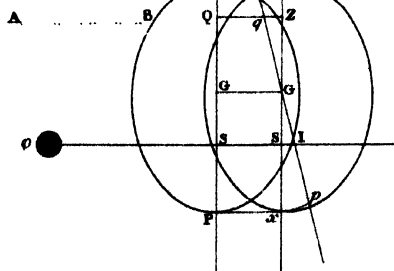


Fig. 9.

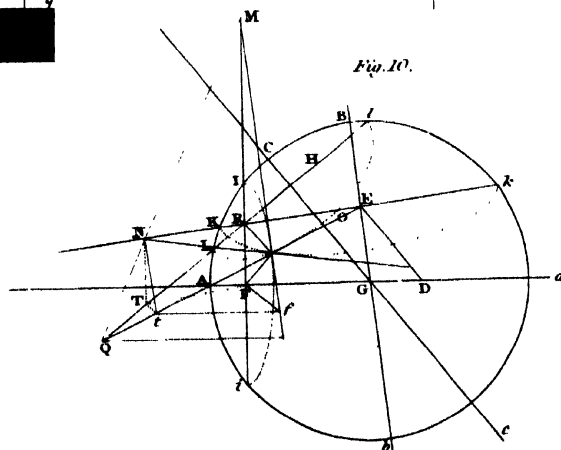


Fig. 1.

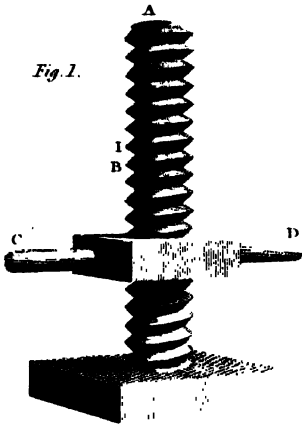


Fig. 3.

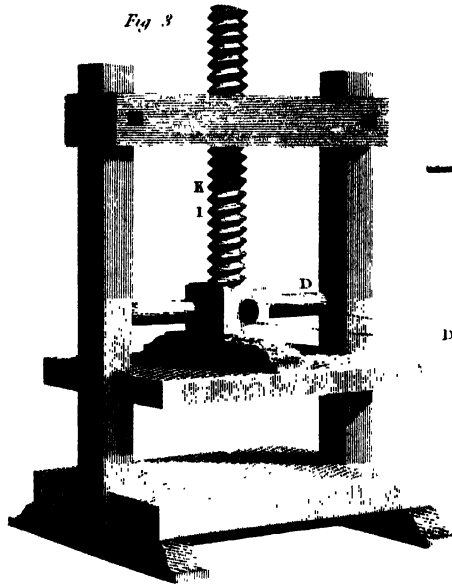


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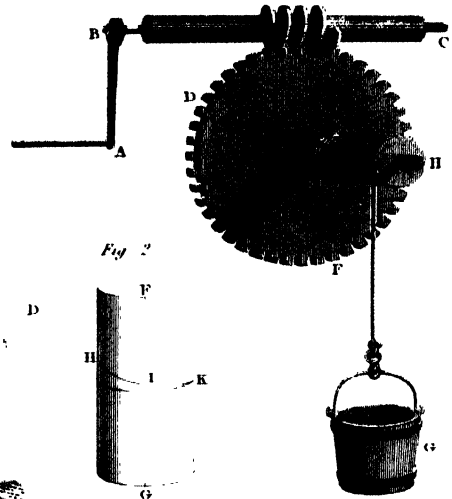


Fig. 2.



SPRING Fig. 6.

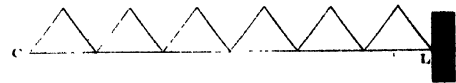


Fig. 7.

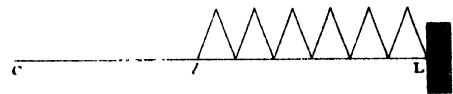


Fig. 8.

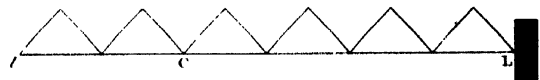


Fig. 10.

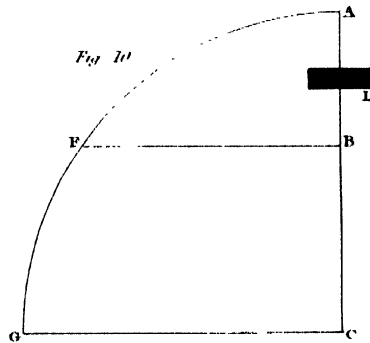
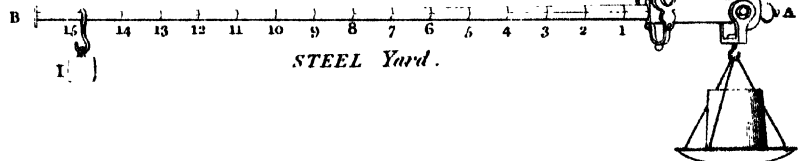
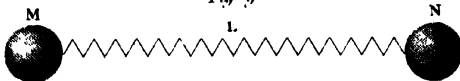


Fig. 11.



STEEL Yard.

Fig. 9.



STRENGTH OF MATERIALS.

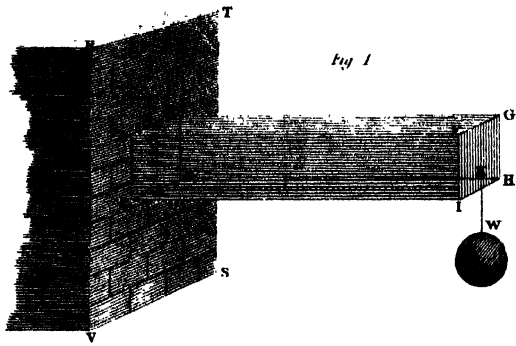


Fig. 1.

Fig. 5.

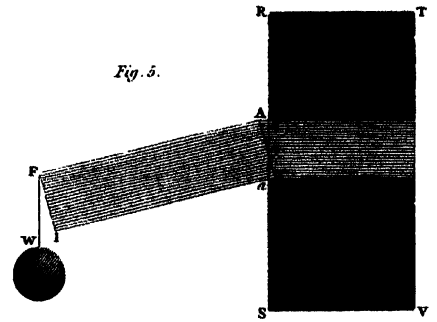


Fig. 3.

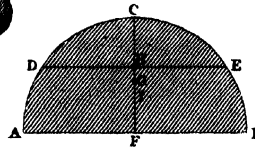


Fig. 2.

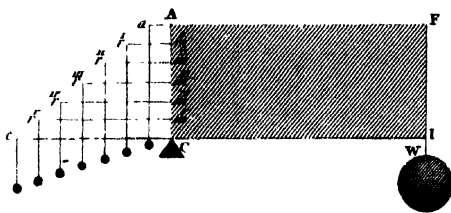


Fig. 4.

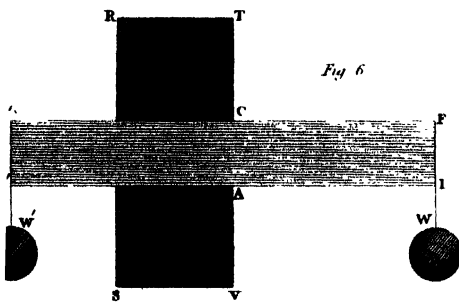
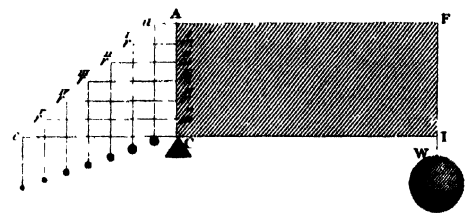


Fig. 6.

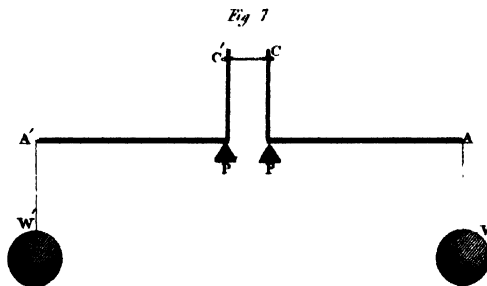


Fig. 7.

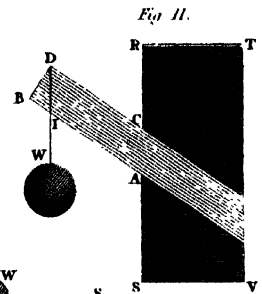


Fig. 11.

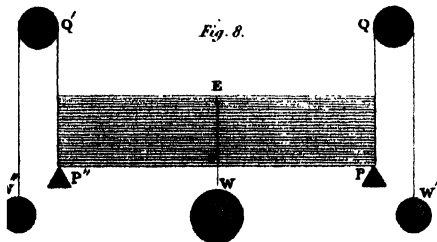


Fig. 8.

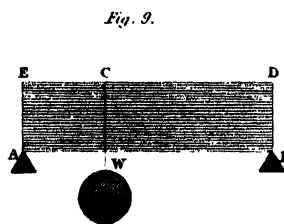


Fig. 9.

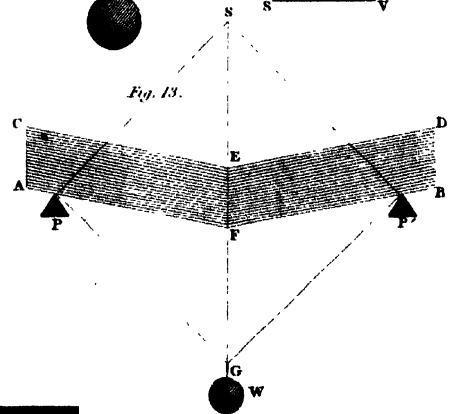


Fig. 13.

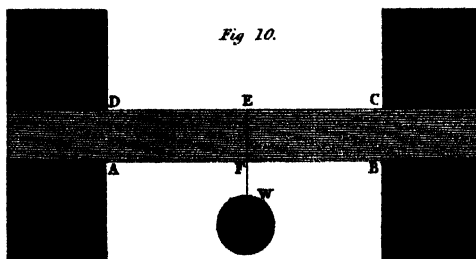


Fig. 10.

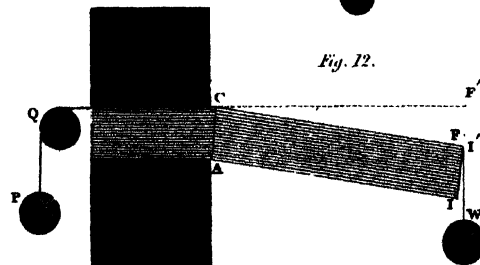


Fig. 12.

MECHANICS.

PLATE

Machines for casting and Drawing Lead Pipes

Fig 3.

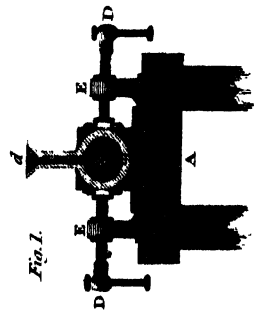


Fig 2.

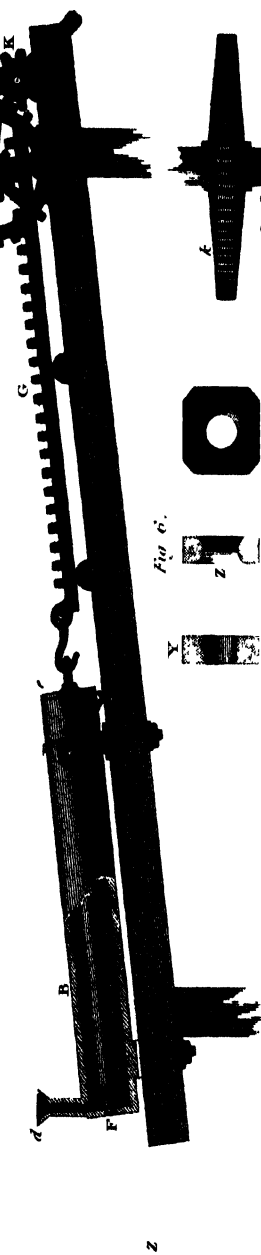
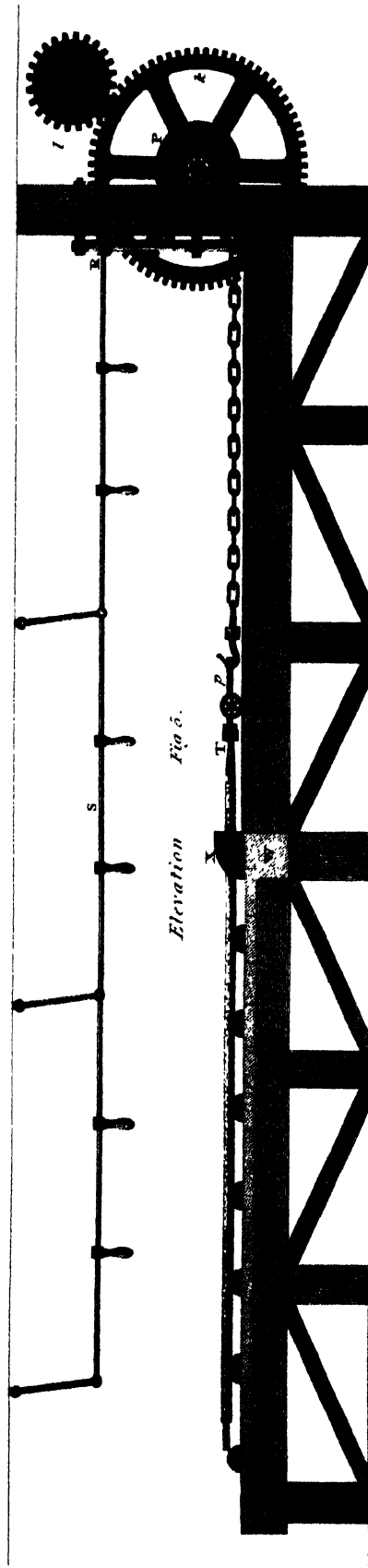
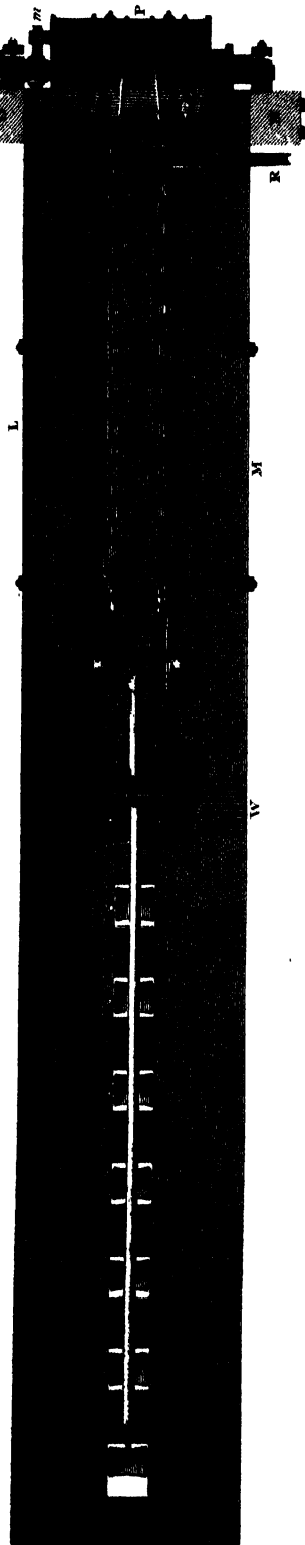


Fig 6.



Plan. Fig 4.



Elevation Fig 5.

Melting-cone

MELTING-CONE, in *Affaying*, is a small vessel made of copper or brass, of a conic figure, and of a nicely polished surface within. Its use is to receive melted metals, and serve for their precipitation, which is effected, when two bodies melted together, and yet not mixing perfectly with one another in the fusion, separate in the cooling into two strata, on account of their different specific gravity. This precipitation might be made in the same vessel in which the fusion is performed; but then the melting-pot or crucible must be broken every time to get it out, whereas the conic shape, and polished surface of this vessel, makes it easily got out without violence. The shape of this vessel is also of another use in the operation; for by means of it, the heavy matter subsiding to a point, is formed into a perfect and separate regulus, even where the whole quantity, as is very frequently the case, has been but very small.

When the quantity of the melted matter is great, it is common to use, instead of this cone, a large brass or iron mortar, or any other conveniently shaped brass or iron vessel. It is necessary, when the cone is of brass, to be cautious that it be not made too hot; for the brittleness of that metal, when hot, makes it easily break, on the striking with any force on that occasion, to make the melted mass fall out.

These, and all other moulds for the receiving melted metals, must always be well heated before the mass is poured into them, lest they should have contracted a moisture from the air, or have been wetted by accident; in which case the melted metal will be thrown out of them with great violence and danger. They ought also to be smeared over with tallow on their inside, that the regulus may be the more easily taken out of them, and the surface of the mould not corroded by the melted mass poured in.

If a very large quantity of a metal is, however, to be received into them, and especially if any thing sulphureous have place among it, this caution of tallowing the moulds does not prove sufficient; for the large quantity of the mass makes it continue hot so long, that this becomes but a slight defence to the surface of the mould. In this case the assayer has recourse to a lute, reduced to a thin pap with water, which being applied in form of a very thin crust, all over the inside of the cone, or mould, soon dries up, indeed, but always preserves the sides of the vessel from the corrosion of the mass. And this caution is found necessary, even when pure copper is melted alone, without any mixture of sulphur.

Merthyr Tydfil

MERTHYR TYDVIL, or *Tudfyl*, in *Geography*, a large and populous market-town, situated in the cwmwd of Senghenydd, cantref of Brenhinol, now the hundred of Caerphilly, and county of Glamorgan, South Wales. It is a place of great antiquity, and is said to derive its name from Tydvil, the daughter of Brechan, prince of Brecknockshire, who was murdered here, along with her father and brother, Rhun Dremrudd, by a party of Saxon marauders, about the close of the fifth century. Tydvil was the wife of Cyngin, son of Cadell, prince of the vale royal and part of Powys, and is reckoned among the number of the ancient British saints. After her death, the Saxons having been expelled by the prowess of her nephew, Nevydd, a church was erected and dedicated to her at this place, and called the church of Merthyr Tydvil, which in Welsh signifies "the Martyr Tydvil."

From this period, nothing occurs deserving of notice relative to Merthyr Tydvil, till about the year 1620, when it was distinguished for its zeal in the cause of non-conformity. Though then trivial in extent and political importance, it was nevertheless a sort of hot-bed, which contributed in no small degree to engender and keep alive, for more than a

century, those religious dissensions, the effects of which still continue visible in the separation of the greater proportion of the inhabitants of Wales from the established church. In 1755 a new era commenced in the history of this place. The extensive and valuable mines in its immediate vicinity had hitherto attracted but little notice. At this time, however, Mr. Bacon particularly directed his attention towards them; and having obtained a lease of a district, extending about eight miles in length, and four in breadth, at the moderate rent of 200*l. per annum*, immediately began operations, and erected extensive works for the smelting and forging of iron. This gentleman continued increasing his establishment till the year 1783, when he deemed it proper to let out the greater part of his property to Mr. Crawshaw, and the remainder to Mr. Hill: at the same time, he reserved to himself a certain tonnage on all the iron manufactured above a specified quantity. The new proprietors soon augmented the works; and the part belonging to Mr. Crawshaw, at Cyfartha, are now by far the largest in this kingdom, and probably in Europe. He employs no fewer than 1500 men, at an average of 30 shillings a week *per man*. The weekly wages paid for labour amount to 1500 pounds.

The average of iron produced from these works is from 180 to 200 tons a week. Six furnaces and two rolling-mills are employed. For procuring blast for the furnaces and working the mills, there are four steam-engines; one of fifty, one of forty, one of twelve, and one of seven horse power. The first engine is connected with the four upper blast-furnaces, to which is a water-engine annexed of nearly the same power. The machinery of this establishment is truly gigantic; and that part of it worked by water is curious, and certainly highly powerful. The great water-wheel is a most extraordinary piece of mechanism: it was constructed under the superintendence of Watkin George, and measures 50 feet in diameter. W. George was then a carpenter employed about the works: he was afterwards taken into partnership, and received 20,000*l.* to give up his share. Besides these works, and those of Mr. Hill, there are two others at Pendarren and Dowlais; the former producing about 140 tons of iron weekly, and the latter about three fourth-parts of that quantity. The total number of smelting-furnaces near this town is seventeen, *viz.* Dowlais four, Pendarren three, Plymouth (Mr. Hill) four, and Cyfartha six.

No fact can better illustrate the magic influence of trade on the condition of a country, than the rapid change which has been effected at Merthyr Tydvil and its neighbourhood. Forty years ago, this town was an inconsiderable village, and contained only a few hundred inhabitants; whereas, by the sole operation of its iron-works, it has risen to be by far the largest and most populous town in Wales. The inhabitants of this parish were estimated at 7705, in 1801; but the population is conjectured to amount to 10,000 persons. In 1803 the money raised for the poor rates, at 6*s.* 6*d.* in the pound, was 1453*l.* 17*s.* 10½*d.* The streets in general are close and confined, and have no proper outlets behind the houses. Considerable improvements, however, have already been made within these last five or six years. Such streets as have been built since that period are much better arranged, and wider than those which were erected earlier. At Pendarren is a large and elegant house, surrounded by beautiful gardens and pleasure-grounds, belonging to Mr. Homfray. The parish church, rebuilt in 1806, is a large and handsome building; and besides it, there is a spacious chapel built by Mr. Crawshay. The meeting-houses for dissenters of different sects are about eleven in number: three Baptists, two Presbyterian, two Independents, two in the Wesley connection, and two in that of Whitfield. A theatre has been lately erected here. There is likewise a philosophical society here, as well as a printing-house, and a book-seller. The inhabitants of this town are chiefly Welsh, and the language spoken in it almost entirely so. Less immorality prevails than might be expected in a place where the population consists chiefly of the lower orders. This is partly owing to the circumstance of the iron-masters and clergymen being usually magistrates for the county, and

partly to the effect of religious instruction. These magistrates have the power of nominating the requisite number of constables, and must submit all their proceedings to the quarter and great sessions. A court of conscience, for the recovery of small debts, has been instituted here by act of parliament, within these three years. This town has three market-places, which are well supplied twice every week, on Wednesdays and Saturdays. It has likewise several fairs during the year.

The weighty and valuable productions of Merthyr Tydvil find an easy conveyance to the sea, by means of a canal which extends hence to Penarth harbour, in the Bristol channel, being navigable as far as Cardiff for vessels of 300 tons, and above that town for barges of 100 tons. This canal, begun about 22 years ago, was completed in 1798.

At the Cyfartha works, where it terminates, it is 568 feet above the level of the sea; which elevation is effected by means of about 40 locks. A new tram road runs nearly by its side, through its whole course, extending altogether 26 miles in length.

Besides its iron ores, the neighbourhood of this town is abundantly productive of other minerals useful in the arts, and consequently subservient to the convenience and happiness of man. Coal, so indispensibly necessary in the manufacture of the iron, is supplied in immense quantities, and of excellent quality. Good mill-stones and stones for paving are likewise abundant; and in the lime-stone rocks are found beds of black and variegated marble, not inferior to any in the kingdom.

About two miles from the town, on the summit of a lofty mountain, is situated a very ancient market-place, where weekly markets have now been held for upwards of 800 years, during the summer season, from the 14th of May till the 14th October. This singular market is still much frequented. Several fairs are likewise held here for cattle, though the houses in the place do not exceed six in number.

Morlais castle stands about three miles to the north-west. It is situated on the summit of a hill, about half a mile from the ancient road over the mountains from Cardiff to Brecknock, overlooking a ravine of great depth, in the bottom of which runs a branch of Taff Vechan river. The area of this castle forms an irregular pentagon, defended on the south and east sides by a very large and deep trench cut in the solid rock. On the north and west sides it is rendered sufficiently strong, by the bold and rugged precipices which overhang the dingle. The whole of this castle is now in ruins. It was built by Ivor Petit, or Ivor Bach, the son of Cedevor, who was no less distinguished for his valour than for the uncommon smallness of his stature. Malkin's *Scenery, Antiquities, and Biography of South Wales*, 2 vols. 8vo. 1807. Carlisle's *Topographical Dictionary of Wales*, 1 vol. 4to. 1811.

Metals

METALS, in *Chemistry*, a class of simple bodies possessing peculiar properties. The ancients, who valued these bodies most for their physical properties, did not bestow the exclusive name of metal on any body which was not malleable. Other bodies, which possessed similar characters, without being malleable, were called semi-metals. The peculiar brilliancy belonging to the metals is perhaps their most generally distinguishing character. The lustre exhibited by mica has some resemblance to the lustre of metals, but it is very inferior in degree, and is merely confined to the surface. The great specific gravity of most metals has been thought a sufficiently distinguishing character. This property, to a certain extent, was very striking. Till the late discoveries of Mr. (Sir H.) Davy, the lightest of the known metals was of greater specific gravity than the densest body which was not a metal. The bases of potash and soda, however, have all the characters of metals, with the exception of being defective in the property just alluded to, since potassium and sodium are of less specific gravity than water. From these facts, therefore, we are no longer allowed to say that all metals are of greater specific gravity than other bodies.

In the present state of our knowledge there appear to be two classes of elementary matter, namely, oxygen, which constitutes one class, and oxydable bodies, or such bodies as combine with oxygen. Of the latter class, out of 45 varieties, there appear to be only five which are not metallic. The metals, therefore, comprise by far the greatest part of the elementary bodies.

Dr. Thomson has divided the metals into four classes :
1. Malleable. 2. Brittle and easily fused. 3. Brittle, and difficultly fused. 4. Refractory.

I. Malleable.

Gold.	8. Mercury.
Platinum.	9. Copper.
Silver.	10. Iron.
Palladium	11. Lead.
Rhodium.	12. Tin.
Iridium.	13. Nickel.
Osmium.	14. Zinc.

II. Brittle, and easily fusible.

1. Bismuth.	3. Tellurium.
2. Antimony.	4. Arsenic.

III. Brittle, and difficultly fusible.

1. Cobalt.	4. Molybdenum.
2. Manganese.	5. Uranium.
3. Chromium.	6. Tungsten.

IV. Refractory.

1. Titanium.	3. Cerium.
2. Columbium.	

Besides the metals arranged in this table, there are a number of others lately discovered by Mr. Davy, which are the bases of some of the earths, and the two fixed alkalies. If the whole of the earths, as well as the two fixed alkalies, have metallic bases, the number of metals to be added to the above will be 13. Those from potash, soda, barytes, strontian, zinc, and magnesia, have already been obtained, and have been named by Mr. Davy, potassium, sodium, barium, strontium, calcium, and magnesium. The four first of these appear to be malleable metals ; the others are not sufficiently known.

Those metals which are not liable to be oxydated by exposure to the air, such as gold, platina, silver, &c. have

been called noble ; while those which become tarnished and corroded, were termed base metals. These distinctions have now become obsolete.

The metals have always, and must continue to be of the utmost importance in chemistry, in the arts and manufactures, and in domestic economy. Their malleability and hardness render them highly fitted for making various vessels and utensils, and their lustre and colour are agreeable to the eye. The properties of hardness and tenacity united, such as belong to iron and steel, are of great utility in various kinds of edge-tools, and the elasticity which is constituted by certain degrees of these two properties, could scarcely be furnished by any other substance than steel ; hence its great usefulness for making springs.

The ductility of some metals is so great, as to admit of its being drawn into wires much finer than a hair. Gold, although the most laminable of all the metals, or which may be made into the thinnest leaves, does not admit of being drawn into the smallest wire, owing to its want of hardness. Iron, in consequence of possessing greater hardness, with a considerable portion of that property by which the particles of bodies attract each other in all situations equally, is capable of being drawn into finer wire than gold. Indeed pure gold is less ductile than when it contains a certain portion of copper. In treating of some of the physical properties of metals, such as malleability, ductility, hardness, and tenacity, much uncertainty has prevailed, from the want of some of these terms having definite meanings.

That property of a metallic bar or wire, by which it resists the action of a weight in the direction of its length, has been called tenacity, and this is always the measure of its strength. This power in metals, however, is evidently dependent upon two properties, one of which is its hardness, and the other a property for which philosophers have no precise word ; perhaps the word flexibility may come the nearest. We mean, however, that property by which its particles can be changed into any situation, without separation. In the drawing of a piece of wire, some of those particles which constitute its thickness, before it passes through the hole of the wire-plate, are, by the process of drawing, brought into the direction of its length. This property in the greatest degree enables a piece of wire, or a thin slip of metal, to be bent backwards and forwards without breaking. A single experiment will satisfy any one of the propriety of these remarks. Take a piece of copper or iron wire, previously well annealed, and it will be found exceedingly flexible, and may be twisted or bent considerably, without breaking. If a weight be hung to it, with a view to break it, it will stretch considerably before it breaks. If a piece of the same wire be drawn through one or two holes, it will be found much stiffer and harder, and of course smaller : it will also be less capable of being bent or twisted without breaking. If, however, a trial be made of its strength, it will require a much greater weight to break it than in the annealed state ; although its diameter is diminished. If the hardness be still increased by these means, a maximum of strength would be found under some joint proportion of the hardness, and the property of bending or twisting, which we may for the present call flexibility. It is on this latter property, with a certain degree of hardness, that the malleability and ductility of metals depend. It requires rather less hardness to make a metal to the best advantage into sheets, than to draw it into wire. This evil, however, of the wire breaking from being soft, may be remedied by making less difference in the size of the holes in the wire-plate. By this means the greatest ductility and malleability may exist under the same degrees of hardness and flexibility.

Metals, with regard to their hardness and flexibility, are very different under different circumstances. Some metals, however, are more susceptible of this change than others. Steel may be so soft and flexible as to bear much twisting, and be easily penetrable by the file, which happens when it is newly annealed; while, if it is heated red-hot, and cooled rapidly, it becomes extremely brittle, and is sufficiently hard to cut glass. Lead, on the contrary, under all circumstances, has the same degree of stiffness and hardness. The same is pretty nearly the case with tin.

Some hints were given under the article LIQUIDITY, which may throw some light on this mysterious property of metals. It is there conjectured, that the particles of bodies may be capable of assuming two states, one in which the particles attract each other equally in all directions. Hence whatever motion may take place among them, the same attraction still exists. It is in this state that bodies can be changed in their figure, without destroying their aggregation.

On the other hand, it is supposed that the particles of bodies, under certain circumstances, may possess polarity; and that the strongest attraction, and, consequently, their greatest hardness, may exist, when the particles are so arranged that opposite poles are presented to each other. Any thing, therefore, which facilitates this change to polarity, will increase the hardness of a body. The crystalline form, which is common to some metals, strongly favours this idea; since metals are always harder in this state, than when their *fibrous form*, as it is called, is brought about. Metals seem to acquire the greatest hardness by cooling rapidly, through a great range of temperature. It is in this change, therefore, that the particles acquire the greatest polarity, and by which the body becomes the most brittle and elastic. Indeed it is on the principle of polarity only, that we are enabled to explain the elasticity of bodies. Heat appears to be the most efficacious in destroying the polar property. The body would, however, regain it by rapid cooling; but by slow cooling, it is rendered soft to the greatest degree of which it is capable, and in the same proportion malleable and inelastic.

The hardness of metals, when they have been annealed, may be considerably increased by hammering, rolling, or wire-drawing. This change appears to be brought about merely by condensation. The small degree of polarity left in the particles will exhibit itself in the elasticity, when the particles are brought nearer together. It will be equally evident that the particles will be attracted with more force, and that the hardness will be increased. The hammering does not appear to increase the hardness of a body which has assumed the crystalline form; under which the greatest polar power is supposed to exist, but rather to diminish it. If a piece of steel plate, which has been hardened and tempered, be hammered carefully, the elasticity and hardness become less. Upon heating it, however, till it becomes blue, the elasticity returns. The hammering, in this instance, deranges the poles of the particles, which the slight heat restores to their proper positions.

From what has been observed it will be easy to infer, that no metal can be malleable under its crystalline or polar form. Several of the metals are scarcely susceptible of this form: among these we may enumerate gold, silver, and lead, and, in all probability, mercury. Others are deprived of it, and become malleable by hammering or rolling at a certain temperature. Of these are copper, brass, iron, steel, tin, and zinc. There are other metals, indeed the greatest part of them, which are not capable of any other than the crystalline form, and hence are not malleable. Of these we may mention antimony, bismuth, arsenic, cobalt, and manganese. What strengthens the idea that the crystalline form is the

cause of the want of softness and malleability, is the circumstance of copper and tin being separately very soft and malleable; though an alloy of these two metals is as hard as steel, and does not possess the least malleability. Cast steel and blistered steel are in the crystalline form, till they have been hammered at a certain temperature. In the first state they are hard and brittle; in the latter, they are flexible, and are increased in tenacity.

Brass wire appears to undergo some change in its arrangement, by hanging up in a damp room, or in situations where the fumes of acids prevail. It becomes so brittle as not to admit of bending to a right angle. This appears to arise from an increase in its polar form, for heating it red-hot partly restores its malleability.

The fusibility of metals is a very valuable property, since it not only admits of their being cast into almost any form, but the refuse can be made into its original form, which allows of great economy.

Some metals are better fitted for casting than others. It is observed, that all those metals of which we have spoken as being susceptible of the crystalline form, are the best calculated to take fine impressions. At that point in which the metal passes from the liquid to the solid form, a sudden expansion takes place, by which the volume is increased, and, in consequence, presses more strongly against the sides of the mould. This is particularly the case with brass, cast iron, and copper with tin. In forming alloys the most fitted for casting, a simple method offers itself. Let the specific gravity of the solid be as much as possible less than the liquid. In such bodies it will be found that the solid metals will float upon the liquid.

The property which metals possess of reflecting light, is highly important in the arts, sciences, and in common life. The surfaces of many of the metals, when they are smooth and polished, reflect almost all the light which falls upon them. White metals reflect more light than those which are coloured. The hardest metals are best fitted for reflectors, because they assume the finest polish. It has been thought that this property depended upon the density of these substances. This idea, however, seems incorrect, since sodium and potassium, which are less dense than water, appear to possess the power of reflecting light equal to many other metals. It is the great quantity of light which they reflect to which they owe their lustre. The great facility with which metallic bodies conduct heat is of incalculable utility in the arts, and in the economy of human life. The boiling of most fluids would be almost impracticable in any other vessels than those of metal.

This property has been applied to great advantage in the process of drying various articles. Large tubes of metal, being filled with steam, are kept constantly at nearly 212°. The goods to be dried are wrapped round the outside of the tube.

The metal gives its heat with such facility, as to dry the substances upon it in a very little time.

Metals are the best conductors of electricity, and hence are highly useful in electrical science, as well as in preserving the lesser conducting substances from the effects of lightning.

The greater number of the metals are acted upon by the air, especially when aided by heat. Metals were thought by the ancients to be compounds of an earth combined with phlogiston. When these bodies were acted upon by the air, they supposed that the phlogiston was separated, leaving behind a calx, or earth. The ancients did not weigh their products, or else they would have found, that although this imaginary substance phlogiston had escaped, yet the residuum was heavier than the original metal. By the greater accu-

racy of modern experimenters, it has been found that the metal is the simple body, and that, by combining with the oxygen of the atmosphere, the metal is converted into a substance of an earthy appearance, which, in modern chemistry, is called an oxyd of the metal.

The bodies formed by the combination of metals with oxygen, exhibit, as well as the metal, an ample field of utility to man. These bodies, in various forms, are valuable auxiliaries in the healing art. Some of them constitute rich pigments of the utmost importance to the arts. Others are not less valuable to the dyer and the bleacher. Several metallic oxyds are used to great advantage for polishing marble, glass, and metals.

METALS for Specula. See SPECULUM.

METALS, Colours from. As metals have a strong texture in their metalline form, so they preserve their natural colours durable, unless corroded or dissolved by particular menstrua, after which their solutions strike particular durable colours, or afford the strongest stains.

Iron dissolved in stale small beer gives the beautiful yellow and different shades of buff colour, used in printing linens and cottons, &c. When sublimed with sal ammoniac it also affords a yellow; and the common iron-moulds made by ink are owing to the iron dissolved in the copperas of which ink is made.

Copper melted with zinc appears of a gold colour; dissolved in aquafortis, it affords a beautiful green; and in any alkali a beautiful blue. And these solutions may be reduced to dry colours by crystallization or evaporation; and the same metal, precipitated out of aquafortis with common salts, gives the turquoise colour to white glass. Tin, a white or colourless metal, affords a light blue colour, when fluxed with antimony and nitre. The same metal is necessary in striking the scarlet dye with aquafortis and cochineal; and its calx, by strong infusion, turns to a glass of an opal colour.

Lead, corroded by the fumes of vinegar, gives the fine white cerus; burnt in a strong naked fire, it becomes the strong red-lead, or minium; and melted into a glass with sand, is of the hyacinth colour. Shaw's Lectures, p. 171.

Silver being dissolved in aquafortis, if chalk be put to the solution, turns of a beautiful purple or amethyst colour; and its own solution, though pale as water, durably stains the nails, skin, or hair, brown or black.

Quicksilver, mixed with brimstone, makes a black mass, and this, by sublimation, affords the beautiful red pigment called cinnabar, or vermilion; and the solution of quicksilver being precipitated with common salt, yields a snow-white powder, which also turns black by being mixed with sulphur.

Gold, dissolved in aqua regia, affords a fine yellow liquor, which stains animal substances beautifully purple; and if the solution be sufficiently weakened with water, and mixed with a solution of tin, a fine red or purple powder may be procured, very useful for staining of glass and pastes to a beautiful red.

It appears, from the experiments of sir Isaac Newton, relating to the changes of colour that take place in pellucid colourless substances, that the less refrangible colours are exhibited by the greater thickness of air, water, and glass; and that as the thickness of those substances is diminished, they reflect the more refrangible colours. Hence he infers, that nothing more is requisite for producing all the colours of natural bodies, than the several sizes and densities of their particles. Accordingly he attributes the colours of permanently coloured bodies to the same cause by which they were produced in colourless substances, viz. to the

various thicknesses of their component particles. But no experiments were made on permanently coloured bodies, in order to establish the truth of sir Isaac Newton's opinion, till the ingenious Mr. Delaval directed his attention to this subject. From observing the circumstances above recited, and more largely illustrated under the article COLOURS, it appeared to him, that, if permanently coloured bodies are subject to the same laws as transparent colourless substances are, all such permanently coloured bodies, whenever the size of their particles is diminished, should undergo a change of colour, by ascending from the less refrangible to the more refrangible colours; and that such bodies, when the size of their particles is augmented, should undergo a contrary change, their colour in this case descending from the more refrangible to the less refrangible colours. In order to confirm this conclusion, he made a great variety of experiments with vegetable, animal, and mineral subjects, whereby the size of their particles, upon which their colours depend, might be diminished or increased. The methods which he used, in order to diminish the size of the particles of those bodies which were the subject of inquiry, were by dissolving, attenuating, &c. by means of chemical solvents, heat, putrefaction, dilution, &c. The contrary effects were brought about by such means as are known to condense, incrassate, or unite the particles of bodies into larger masses, as by coagulation, precipitation, evaporation, by diminishing the force of the solvents, &c. The metals afforded him numerous instances in confirmation of the doctrine above explained; for almost every operation, to which they are subject, exhibits a change of colour corresponding to this doctrine. This is particularly the case with regard to the imperfect metals; for every change of their texture is accompanied by a correspondent change of colour. We can only enumerate some of the principal results which Mr. Delaval obtained from a great number of well-conducted experiments. Thus, the green vitriol of iron is changed, in proportion as it is deprived of its solvent part, by exposing it to a strong heat, &c. to yellow, orange, red, and purple; and by a contrary process, viz. by a farther attenuation, by means of the phlogisticated lixivium, in the process of Prussian blue, &c. the colour of the iron ascends from green to blue; so that all the primary colours are produced from the same metal, in proportion as its particles are attenuated or incrassated. It appears, likewise, that when iron is divided into very small parts by means of a large quantity of glass, and by a violent heat, its colour is blue; but in proportion as it is less divided, by the mixture of a smaller quantity of glass, or the application of less heat, its colours are green, yellow, and red. From iron dissolved in its several menstrua, colours are produced in proportion as the solvent power of those menstrua is greater or less. Thus, iron dissolved in its strongest acid solvent, the vitriolic acid, gives green; in its weaker acid solvents, the marine and nitrous acids, yellow and orange; and in its weakest acid solvents, the vegetable acids, red. The colours of the calces of iron precipitated from its solution in the vitriolic and nitrous acid, descend from green to yellow, and from yellow to red; whereas the changes of colour arising from the solution of these calces, proceed in a contrary order, and ascend. Mineral substances are also frequently impregnated with iron, and their colours correspond with the state of the iron contained in them.

In the same manner the colours of the solution of mercury in the nitrous acid vary, in proportion as the solvent is extricated from it, from yellow to orange, and then to red. Thus also, those substances which have the greatest affinity with the acid of the corrosive sublimate produced

by the solution of mercury in the marine acid, disengage from its solution a red precipitate; and those, whose affinity with it is less, produce a yellow one. But these colours are liable to some variation, according to the greater or less quantity of acid in the solution. Mercury dissolved in the vitriolic and in the vegetable acids, exhibits, in proportion as its solvent is taken from it, the same colours which, under similar circumstances, are afforded by that metal dissolved in the other acids. All these mercurial preparations become red, when they are deprived of the principal part of their menstruum; and mercury calcined by heat, without the addition of any acid, acquires the same colour. Its colour, however, is subject to variation, from the action of its solvents; and thus the phosphoric acid changes the red to yellow and white. The same law obtains in the changes of colour to which the mineral manganese is subject; for Mr. Delaval found, that by means of the different degrees of power in the several solvents, these colours were produced in their regular prismatic order, *viz.* yellow, green, blue, purple, and red. The various phenomena of the sympathetic ink of M. Hellot conform to the same law, and are urged by Mr. Delaval as arguments to establish it. Heat and cold, he observes, are not necessary agents in the production or suppression of the colour. But it appears, that the alterations are effected by the moisture of the air, attracted by the saline matter when cold, and expelled from it when heated. When this ink is exposed to a moderate heat, in a white China cup, and when the greater part of the water is evaporated, the saline matter becomes green. This colour arises from a superfluous quantity of the marine acid, which soon flies off, and leaves the remaining part blue, slightly inclining to green. It also forms a hard dry mass, which, in a few minutes after its removal from the fire, grows moist, and assumes a light red colour. These alterations may be often renewed, by alternately heating and cooling the coloured matter; which does not again become green, after the superfluous marine acid is once evaporated. But a drop of spirit of salt, added to the red or blue mass, immediately renders it green. When preparations of cobalt are acted upon merely by heat, the order of the changes of colour effected in them, is such as, in other instances, constantly arises from that means of attenuation. Thus, when the yellow solution of this mineral, in the marine acid, is heated, it assumes a green colour, passing from a less to a more refrangible colour. When this solution is cooled, the yellow is restored.

Mr. Delaval observes, that as the inflammable matter, in the entire metals, acts strongly on the rays of light, it is necessary to calcine or to divide them into extremely minute

particles, in order to examine separately the action of the calx, or fixed matter, on the rays of light. In order, therefore, to examine all the metals in the like circumstances, by reducing them into the smallest particles, and depriving them of their phlogiston as much as possible, he exposed each of them, united with a proper quantity of the purest glass, without any additional ingredient, to the greatest degree of fire which they are capable of bearing, without having all colour whatever destroyed. In this state it appears, from a variety of experiments and facts, that they actually do, without any exception, exhibit colour in the order of their densities as follow: gold, red; lead, orange; silver, yellow; copper, green; and iron, blue. He has also shewn that the other preparations of the metals, *viz.* their solutions, precipitates, crystals, &c. do for the most part exhibit the same colour, in the order of their densities, though not so invariably as their glasses; some small variation of colour happening in the more imperfect metals, probably from a change of density in their different preparations. Thus, gold acquires a red colour, by a minute division of its particles, without any addition. In the process of calcining lead in the furnace, the first of the primary colours which it acquires is yellow; the calx passing from that colour through orange into red. This variety of colours proceeds from the imperfection of the metal; which, probably, during its calcination (as our author supposed), receives a small portion of phlogiston, as well as air; for the effect of such an union must probably be a change of colour from orange to red: as sir Isaac Newton has shewn, that bodies reflect more strongly in proportion as they possess more phlogiston; and that the less refrangible colours require a greater power to reflect them. The preparations of silver are yellow; the two most imperfect metals, copper and iron, being very easily acted upon by almost all menstrua, the colours of their solutions, &c. *viz.* green and blue, are apt to change into each other's order; the copper in some solvents becoming blue, and the iron green, and in other solvents *vice versa*; which probably depends on the increase or diminution of their densities. The preparations, &c. of mercury have been already examined. The specific gravity of platina being nearly equal to that of gold, it is found, agreeably to the Newtonian doctrine, confirmed by Mr. Delaval, that the precipitates and crystals obtained from solutions of this metal are red; and that a solution of it in aqua regia to perfect saturation is of a dark red, though, when diluted, yellow. Delaval's Experimental Inquiry into the Cause of the Changes of Colours in opaque and coloured Bodies, &c. 1777, passim. Phil. Trans. vol. lv. art. 3, p. 10, &c.

Mill

MILL, in propriety, denotes a machine for grinding corn, &c. but, in a more general signification, is applied to all machines whose action depends on a circular motion.

Of these there are several kinds, according to the various methods of applying the moving power; as water-mills, wind-mills, mills worked by horses, &c.

Few people are ignorant, that corn is ground by two mill-stones, placed one above the other, without touching.

The lower mill-stone is immovable, but the upper one turns upon a spindle. The opposite surfaces of the two stones, which act to grind the corn, are not plane or flat; but the upper one is hollow, and the under one swells up; each of them being of a conic figure, whose axis indeed is very short, in proportion to the diameter of its base; for the upper one being six feet in diameter, is hollowed but about one inch at its centre; and the lower one rises but about three-fourths of an inch. These two mill-stones come nearer and nearer towards their circumference, whereby the corn that falls from the hopper has room to insinuate between them as far as two-thirds of the radius, which is the place where it begins to be ground, and where it makes the greatest resistance that it is capable of; the space between the two stones being in that place about but two-thirds or three-fourths of the thickness of a grain of corn. But as the millers have the liberty of raising or sinking the upper stone a little, they can proportion its distance from the lower one, according as they would have the flour finer or coarser.

In order to cut and grind the corn, both the upper and under mill-stones have channels or furrows cut in them, proceeding obliquely from the centre towards the circumference. And these furrows are each cut perpendicularly on one side, and obliquely on the other, into the stone; which gives each furrow a sharp edge, and in the two stones, they come, as it were, against one another, like the edges of a pair of scissars; and so cut the corn to make it grind the easier, when it falls upon the places between the furrows. These are cut the same way in both stones when they lie upon their backs, which makes them run cross-ways to each other, when the upper stone is inverted by turning its furrowed surface towards that of the lower. For if the furrows of both stones lay the same way, a great deal of the corn would be drove onward in the lower furrows, and so come out from between the stones without ever being cut. When the furrows become blunt and shallow by wearing, the running stone must be taken up, and both stones new dress'd with a chisel and hammer. But, by this repeated operation, their thicknesses, and consequently their weight, diminish; and it is observed, that when they come to have but three-quarters, or half of the thickness which they had when new, they produce but three-quarters or half the flour which they yielded at the beginning.

The circular motion of the upper mill-stone brings the corn out of the hopper by jerks, and causes it to recede from the centre towards the circumference, where, being quite reduced to flour, it is thrown out of the mill, by the centrifugal force of the stone, through a hole provided on purpose.

The diameter of common mill-stones, according to Dr. Desaguliers, is from five to seven feet, and their thickness, twelve, fifteen, or eighteen inches: they last thirty-five or forty years, and when they have been long used, so that their thickness is considerably diminished, they are cut anew, to give their surface a contrary figure to what they had before: so that the upper mill-stone is made the lower.

In water-mills, the momentum of the water is the moving power, and the attrition of the two stones in grinding is the force to be overcome. Of these there are two kinds, viz. those where the force of the water is applied above the wheel, and those where it is applied below the wheel; the former being called over-shot, and the latter under-shot mills: and to these we may add a breast-mill, where the water strikes against the middle of the wheel.

In a common breast-mill, where the fall of water may be about ten feet, A A, (*Plate XXIII. Mechanics, fig. 1.*) is the great wheel, which is generally about seventeen or eighteen feet diameter, from *a* the outermost edge of any float board, to *b*, that of its opposite float. To this wheel the water is conveyed through a channel, and falling upon the wheel, turns it round. On the axis B B, of this wheel, and within the mill-house, is a wheel D, about eight or nine feet diameter, having sixty-one cogs, which turn a trundle E, containing ten upright staves or rounds; and when this is the number of cogs and rounds, the trundle will make $6\frac{1}{5}$ revolutions for one revolution of the wheel. The reason of adding an odd cog, called the hunting cog, to the wheel, is this; that, as every cog comes to the trundle, it may take the next staff or round behind the one which it took in the former revolution, and thus it will wear all the parts of the cogs and rounds which work upon one another equally, and to equal distances from one another in a little time; and make a true uniform motion throughout the whole work. The trundle is fixed upon an iron axis called the spindle, the lower end of which turns in a brass foot, fixed at F, in the horizontal beam S T, called the bridge-tree; and the upper part of the spindle turns in a wooden bush fixed into the lower mill-stone, which lies upon beams in the floor Y Y. The top part of the spindle above the bush is square, and goes into a square hole in a strong iron cross, *abcd*, (*fig. 2.*) called the rynd; under which, and close to the bush, is a round piece of thick leather upon the spindle, which it turns round at the same time as it does the rynd. The rynd is let into grooves in the under surface of the running mill-stone G, (*fig. 1.*) and so turns it round in the same time that the trundle E is turned round by the cog-wheel D. This mill-stone has a large hole quite through its middle, called the eye of the stone, through which the middle part of the rynd and upper end of the spindle may be seen; whilst the four ends of the rynd lie hid below the stone in their grooves.

The end T of the bridge-tree T S (which supports the upper mill-stone G upon the spindle) is fixed into a hole in the wall; and the end S is let into a beam Q R called the brayer, whose end R remains fixed in a mortise: and its other end Q hangs by a strong iron rod P, which goes through the floor Y Y, and has a screw-nut on its top at O; by the turning of which nut, the end Q of the brayer is raised or depressed at pleasure; and, consequently, the bridge-tree T S and upper mill-stone. By this means the upper mill-stone may be set as close to the under one, or raised as high from it, as the miller pleases. The nearer the mill-stones are to one another, the finer they grind the corn; and the more remote from one another, the coarser.

The upper mill-stone G is inclosed in a round box H, which does not touch it any where; and is about an inch distant from its edge all around. On the top of this box stands a frame for holding the hopper *kk*, to which is hung the shoe I, by two lines fastened to the hind-part of it, fixed upon hooks in the hopper, and by one end of the

crook-string K fastened to the fore-part of it at *i*; the other end being twisted round the pin L. As the pin is turned one way, the string draws up the shoe closer to the hopper, and so lessens the aperture between them; and as the pin is turned the other way, it lets down the shoe, and enlarges the aperture.

If the shoe be drawn up quite to the hopper, no corn can fall from the hopper into the mill; if it be let a little down, some will fall: and the quantity will be more or less, according as the shoe is more or less let down. For the hopper is open at bottom, and there is a hole in the bottom of the shoe, not directly under the bottom of the hopper, but forwarder towards the end *i*, over the middle of the eye of the mill-stone.

There is a square hole in the top of the spindle, in which is put the feeder *e* (fig. 2.); this feeder (as the spindle turns round) jogs the shoe three times in each revolution, and so causes the corn to run constantly down from the hopper, through the shoe, into the eye of the mill-stone, where it falls upon the top of the rynd, and is, by the motion of the rynd and the leather under it, thrown below the upper stone, and ground between it and the lower one. The violent motion of the stone creates a centrifugal force in the corn going round with it, by which means it gets farther and farther from the centre, as in a spiral, in every revolution, until it be thrown quite out; and, being then ground, it falls through a spout M, called the mill-eye, into the trough N. When the mill is fed too fast, the corn bears up the stone, and is ground too coarse; and besides, it clogs the mill so as to make it go too slow. When the mill is too slowly fed, it goes too fast, and the stones, by their attrition, are apt to strike fire against one another. Both which inconveniences are avoided by turning the pin L backwards or forwards, which draws up or lets down the shoe; and so regulates the feeding as the miller sees convenient.

Sometimes, where there is a sufficient quantity of water, the cog-wheel in fig. 1. turns a large trundle, on whose axis is fixed a horizontal wheel, with cogs all around its edge, turning two trundles at the same time; whose axis or spindles turn two mill-stones. When there is not work for them both, either may be made to lie quiet, by taking out one of the flaves of its trundle, and turning the vacant place towards the horizontal cog-wheel. And there may be a wheel fixed on the upper end of the great upright axle of this wheel for turning a couple of boulting-mills; and other work for drawing up the sacks, fanning and cleaning the corn, sharpening of tools, &c. As the water acts upon an over-shot mill both by impulse and weight, so does it likewise upon a breast-mill, or that where the water comes upon the breast or middle part of the wheel: and here, though the weight of the water is not so great as in the over-shot mill, being contained in the buckets of the lower quarter only; yet the impulse of the water is much greater, the height of the water being increased nearly the semi-diameter of the great wheel, all other things being equal. If the height of the water remain the same, the aperture of the penstock must be enlarged to nearly twice the area, that the force may be the same; so that to produce the same effect, twice as much water is necessary for the breast-mill as for an over-shot one, every thing else being the same.

Mr. Ferguson observes, that where there is but a small quantity of water, and a fall great enough for the wheel to lie under it, the bucket or over-shot wheel is always used. But where there is a large body of water, with a little fall, the breast or float-board wheel must take place. As to the under-shot mill, it is evident there can be only the impulse from the water; and therefore, the height of the water re-

maining the same, there must be a larger aperture of the penstock for the discharge of a greater quantity of water in the same time, in order to produce the same effect as the over-shot or breast-mill; whence a greater expence of water will be made here than in any other mill, and can only be supplied for a constancy by a river; and where this can be had, the under-shot is the easiest, cheapest, and most simple structure, of which a mill is capable. Dr. Defaguliers, having had occasion to examine many under-shot and over-shot mills, generally found that a well made over-shot mill ground as much corn, in the same time as an under-shot mill with ten times less water; supposing the fall of water at the over-shot to be twenty feet, and at the under-shot to be about six or seven feet: and he generally observed, that the wheel of the over-shot mill was of fifteen or sixteen feet diameter, with a head of water of four or five feet, to drive the water into the buckets with some momentum.

Mr. Ferguson has given the following directions how to construct water-mills, so as to be in the greatest degree of perfection; and also a table calculated from his rules, for the sake of those mill-wrights who either cannot calculate, or do not like to take the trouble.

When the float-boards of the water-wheel move with a third part of the velocity of the water that acts upon them, the water has the greatest power to turn the mill: and when the mill-stone makes about sixty revolutions in a minute, it is found to do its work the best. For, when it makes but about forty or fifty, it grinds too slowly, and when it makes more than seventy, it heats the meal too much, and cuts the bran so small, that a great part thereof mixes with the meal, and cannot be separated from it by sifting or boulting. Consequently, the utmost perfection of mill-work lies in making the train so, as that the mill-stone shall make about sixty turns in a minute when the water-wheel moves with a third part of the velocity of the water. To have it so, observe the following rules:

1. Measure the perpendicular height of the fall of water, in feet, above the middle of the aperture, where it is let out to act by impulse against the float-boards on the lowest side of the under-shot wheel.
2. Multiply this constant number 64.2882, by the height of the fall in feet, and extract the square root of the product, which shall be the velocity of the water at the bottom of the fall; or the number of feet the water moves *per* second.
3. Divide the velocity of the water by 3; and the quotient shall be the velocity of the floats of the wheel in feet *per* second.
4. Divide the circumference of the wheel, in feet, by the velocity of its floats; and the quotient shall be the number of seconds in one turn or revolution of the great water-wheel on whose axis the cog-wheel that turns the trundle is fixed.
5. Divide 60 by the number of seconds in a turn of the water-wheel or cog-wheel; and the quotient shall be the number of turns of either of these wheels in a minute.
6. By this number of turns divide 60 (the number of turns the mill-stone ought to have in a minute) and the quotient shall be the number of turns the mill-stone ought to have for one turn of the water or cog-wheel. Then,
7. As the required number of turns of the mill-stone in a minute is to the number of turns of the cog-wheel in a minute, so must the number of cogs in the wheel be to the number of flaves in the trundle on the axis of the mill-stone, in the nearest whole number that can be found. By these rules the following table is calculated; in which the diameter of the water-wheel is supposed to be 18 feet, (and conse-

quently its circumference $56\frac{1}{2}$ feet,) and the diameter of the mill-stone to be five feet.

Velocity of the of the water in feet per	lined number of for each turn of the	of turns of the mill-stone by the cogs and flaves.	number of the mill-stone for the cogs and flaves	Cogs. Stav.	of turns of the mill-stone by the cogs and flaves.
8.02	2.67	2.68	21.20	127 6	21.17 59.91
11.40	3.72	4.00	15.00	105	15.00 60.00
13.89	4.63	4.91	12.22	98	12.23 60.14
16.04	5.35	5.67	10.58	95	10.56 59.87
17.93	5.98	6.34	9.16	85	9.44 59.84
19.64	6.53	6.94	8.01	78	8.66 60.10
21.21	7.07	7.50	8.00	72	8.00 60.00
22.68	7.56	8.02	7.48	67	7.44 59.67
24.05	8.02	8.51	7.05	70 10	7.00 59.57
25.35	8.45	8.97	6.69	67 10	6.70 60.09
26.59	8.86	9.40	6.38	64 10	6.40 60.16
27.77	9.26	9.82	6.11	61 10	6.10 59.90
28.91	9.64	10.22	5.87	59 10	5.90 60.18
30.00	10.00	10.60	5.66	56 10	5.60 59.36
31.03	10.35	10.99	5.46	53 10	5.40 60.48
32.07	10.69	11.34	5.29	53 10	5.30 60.10
33.06	11.02	11.70	5.13	51 10	5.10 59.67
34.02	11.34	12.02	4.90	50 10	5.00 60.10
34.95	11.65	12.37	4.83	49 10	4.80 60.61
35.86	11.92	12.68	4.73	47 10	4.70 59.59

Example.—Suppose an under-shot mill is to be built where the perpendicular height of the fall of water is nine feet: it is required to find how many cogs must be in the wheel, and how many staves in the trundle, to make the mill-stone go about 60 times round in a minute, while the water-wheel floats move with a third part of the velocity with which the water spouts against them from the aperture at the bottom of the fall.

Find 9 (the height of the fall) in the first column of the table; then against that number, in the sixth column, is 70, for the number of cogs in the wheel, and 10 for the number of staves in the trundle: and by these numbers, we find in the eighth column that the mill-stone will make $59\frac{57}{60}$ turns in a minute, which is within half a turn of 60, and near enough for the purpose; as it is not absolutely requisite that there should be just 60 without any fraction: and throughout the whole table the number of turns is not quite one more or less than 60.

The diameter of the wheel being eighteen feet, and the fall of water nine feet, the second column shews the velocity of the water at the bottom of the fall, to be $24\frac{3}{5}$ feet per second; the third column the velocity of the float-boards of the wheel to be $8\frac{1}{10}$ feet per second; the fourth column shews that the wheel will make $8\frac{1}{10}$ turns in a minute; and the sixth column shews that for the mill-stone to make exactly 60 turns in a minute, it ought to make $7\frac{1}{10}$ (or seven turns and five hundred parts of a turn) for one turn of the wheel.

Dr. Barker has invented a water-mill, that has neither wheel nor trundle: this is represented in *fig. 3*, in which A is a pipe or channel that brings water to the upright tube B. The water runs down the tube, and thence into the horizontal trunk C, and runs out through holes at *d* and *e* near the ends of the trunk on the contrary sides thereof.

The upright spindle D is fixed in the bottom of the trunk, and screwed to it below by the nut *g*; and is fixed into the trunk by two cross-bars at *f*: so that if the tube B and trunk C be turned round, the spindle D will be turned also.

The top of the spindle goes square into the rynd of the upper mill-stone H, as in common mills; and as the trunk, tube, and spindle turn round, the mill-stone is turned round thereby. The lower, or quiescent mill-stone, is represented by I; and K is the floor on which it rests, and wherein is the hole L for letting the meal run through, and fall down into a trough which may be about M. The hoop or case that goes round the mill-stone rests on the floor K, and supports the hopper, in the common way. The lower end of the spindle turns in a hole in the bridge-tree G F, which supports the mill-stone, tube, spindle, and trunk. This tree is moveable on a pin at *b*, and its other end is supported by an iron rod N fixed into it, the top of the rod going through the fixed bracket O, and having a screw-nut *o* upon it, above the bracket. By turning this nut forward or backward, the mill-stone is raised or lowered at pleasure.

Whilst the tube B is kept full of water from the pipe A, and the water continues to run out from the ends of the trunk; the upper mill-stone H, together with the trunk, tube, and spindle, turns round. But if the holes in the trunk were stopped, no motion would ensue; even though the tube and trunk were full of water. For,

If there were no hole in the trunk, the pressure of the water would be equal against all parts of its sides within. But, when the water has free egress through the holes, its pressure there is entirely removed; and the pressure against the parts of the sides which are opposite to the holes, turns the machine. See Defaguliers's *Exp. Phil.* vol. ii. p. 417, &c. p. 431, &c. p. 459, &c. Fergusson's *Mechanics*, p. 45, &c. 4to. ed. and Supp. p. 10. See also on this subject, an elaborate paper of Mr. Smeaton, containing an account of a number of experiments, in order to estimate the natural powers of water and wind to turn mills, in the *Phil. Transf.* vol. li. art. 18 p. 100, &c.

The description of a mill, which we have given above in the words of the late ingenious Mr. Fergusson, is very correct. The improvements of late years, which have been made in mills for grinding corn, relate to the manner of their construction, and the proportions of the wheel-work, for giving motion to the mill-stones, by which the grinding is performed in the manner described. The late Mr. John Smeaton, F.R.S., was celebrated for his accuracy and judgment in the proportions of his mills, particularly those turned by water. We shall, under the article *WATER-WHEELS*, give some account of his principles; and under this head we shall describe a steam flour-mill, which was erected from his designs, at the victualling house for the navy at Deptford, in 1781. This was before the steam-engine of Mr. Watt was brought to the perfection it has since attained; and as the old atmospheric engine was thought to be unfit for producing a rotatory motion, Mr. Smeaton erected a common steam-engine to pump up water for the supply of a large overshot water-wheel, which actuated the mill. *Fig. 1. of Plate XXXIV. Mechanics*, represents the whole mill, by a longitudinal section of the house; and *fig. 2*,

another section, taken perpendicular to the former. The mill is double, that is, the water-wheel, A A, is situated between two buildings, only one of which is represented in *fig. 2*; and the wall, B B, of the other is one side of a house, containing exactly the same machinery as that which is delineated. Over the water-wheel two large cisterns, or troughs, C, D, are placed, communicating with each other by a large iron pipe E, *fig. 1*; and one of these troughs, C, has a pipe or trough, leading water into it, from the pump of the steam-engine supplying the water for the mill: in the other trough, D, is a shuttle *a*, which being raised up, permits the water to issue from a hole in the end of the trough, and fly forwards horizontally through a proper chute, or pentrough, into the buckets of the wheel A. The form of these buckets is shewn by *fig. 1*, a portion of the wheel being represented in section for that purpose. The buckets, which are thus filled at the top of the wheel, descend by their weight, turning the wheel round, till they come to the lowest part of the wheel; and here, by the buckets becoming inverted, the water is discharged from them, and they go up empty to the top of the wheel, where they are filled again from the trough. In this manner, one side of the wheel being always loaded by the buckets full of water, and the other side being empty, it has a constant tendency to turn round. The axis of the wheel has a large spur-wheel, E, fixed upon its extreme end, which being furnished with a double row of cogs, as shewn in *fig. 2*, communicates motion to the lanterns or trundles, F, G, one above, and the other below it: the latter, G, is fixed upon the end of an horizontal shaft H H, extending beneath the mill-stones, situated at I I and L: it actuates the upper stone of each pair, by means of crown or face-wheels K, which turn the pinions fixed at the lower ends of the respective spindle *dd*. The upper trundle, F, is fixed upon a shaft, which carries two face-wheels, *e*, *f*: the teeth of these wheels are opposite to each other, and either of them can be made to work a pinion, *g*, *fig. 1*, fixed upon the end of an axis *h*, which at the other end has a cog-wheel turning a pinion at *k*, on the end of the spindle of a machine, M, for dressing flour. This machine consists of a hollow cylinder or frame, covered with wire-cloth of different degrees of fineness; the finest being at the end A, which is the most elevated, for the axis of the cylinder is inclined in the direction of the dotted line: every one of the lengths, as it goes towards the other end, is covered with a coarser kind of wire-cloth, for sifting the flour. Within this cylinder, which is stationary, a reel is situated; its axis being exactly in the centre of the cylinder, and turned round by the pinion *k*: the rails of this reel are provided with hair brushes, which, as they revolve, brush against the interior wire surface of the cylinder. The machine is provided with a shoe or jigger, very similar to that of the mill-stones, to bring down the flour or meal through a trough, from the floor above, where it is kept after being ground: the meal, being by this means gradually fed into the cylinder, is, by the motion of the brushes on the reel, sifted or rubbed through the wire: the finest of the flour will of course go through at the upper end, but no other kind; the second through the next division, and so on till the bran falls out at the end of the cylinder, being too coarse to go through any of the wires. The cylinder is enclosed in a tight and close box M, to prevent waste by the flour flying about; and the box has partitions, which divide it into as many lengths as the cylinder has different kinds of wire. Thus each division of the box receives a different quality of flour; and spouts being fixed, which go down into the floor beneath, sacks can be filled at them without waste or inconvenience.

The pinion *g*, for turning the dressing machine, can be

made to turn either way about, by engaging it with the teeth of either of the cog-wheels *e*, *f*, which acting on the opposite sides of the pinion *g*, give the means of turning it in either direction at pleasure. The pinion is of such a diameter, that it cannot be engaged with both wheels at once; and the upright lever *r*, which supports the pivot of its axis *h*, can be thrown to either side, as is shewn in *fig. 2*: for its lower end moves on a centre at the floor, and at top it is guided by a groove in a piece of wood, fixed to the ceiling, and can be fastened at either side by a pin, so as to throw the pinion in gear with either *e* or *f*. The object of this contrivance is, that when the machine, M, has for a long time been running in one direction, and its brushes become worse, or bent on one side, its motion may be reversed, to give them an equal wear on the opposite side. The wheel, *e*, has another fixed to it at the back (see *fig. 2*), which actuates a cog-wheel N, upon the end of a roller R, having a rope wound round it, for drawing up sacks of corn or flour from one floor of the mill to another. This rope passes upwards from the roller to the roof of the building, where it passes over a pulley, and thence descends through square holes in the several floors to the ground. These holes are covered by double doors, opening upwards, so that a sack, being drawn up, opens the door, which falls down as soon as it has passed. The wheel, N, of the sack-roller can be disengaged at pleasure from the cog-wheel, *e*, which turns it; and then the rope can be unwound and run down again, to fetch up another sack. This disengagement of the wheel is effected by the same means as described of the upright lever *r*; and a line being conducted from the top of the lever, over proper pullies, into various parts of the mill, the miller can, by pulling this line, disengage the roller at pleasure, to draw up or let down a sack. A pinion and shaft, similar to *g* and *h*, *fig. 1*, may be placed on the opposite side of the wheels, *e* and *f*, to work another dressing machine at the opposite side of the mill, or what is called a bolting machine. This is rather of a different construction, being the original flour-dressing machine: it consists of a reel like the former, but without any brushes; and upon this, instead of a wire-cylinder, a cloth like a sack, cut open at the bottom, is fastened, and revolves with it; the flour, being introduced by a feeding-shoe into this, is sifted round in the revolving cloth, and the fine flour passes through. To prevent the flour accumulating at any one side of the cloth into a bag, and swinging round with it, without sifting, four rails are fixed in the machine, parallel to the axis; and if the cloth swings out by the weight of the flour within it, the cloth strikes against these rails, and the flour is thus shaken through it into the chest or case of the machine.

The lower figures of the plate contain the development of the parts of the mill, tending to explain their construction. *Figs. 3, 4, and 5*, shew the cast-iron axis for the water-wheel; N is the cylindric shaft, and *h, h*, its two necks, which lay on bearings in the wall of the mill, and bear the weight: beyond these necks the axis has a square box, O O, at each end, for framing the great cog-wheels upon. The manner of attaching the arms of the great water-wheel to the shaft is this: two circular plates or flaunches, P, P, *fig. 3*, are cast upon the axis; and against each of these 12 arms, Q, Q, are bolted: they are placed against the flaunch, tending to the centre, and the spaces between them are filled up by wooden pieces, as shewn by *r, r, r*, *fig. 4*: two iron rings, R and S, are placed over the arms, and a bolt put through each arm, to attach it to the flaunch, and to the axis; the wooden pieces, *r, r*, are kept in their places by a wedge driven through each, within the great hoop R, and by means of these wedges the pieces, *r, r*, can

at any time be drawn up towards the centre, to hold all the arms fast in their places.

This method of framing water-wheels was used with great success by Mr. Smeaton in many instances, and was found to answer the purpose extremely well, being a great improvement upon the old method of mortising the arms into a wooden shaft.

Figs. 6, 7, and 8, shew one of the spindles for the mill-stones H and L, *fig. 2*: it is a straight iron axis, *d*, formed to a pivot, *s*, at the lower end, which rests and turns in a piece of brass: near the upper end of the spindle another neck or pivot, *t*, is formed, and runs in a collar, in the centre of the nether or lower mill-stone, whilst the upper one is hung upon the arms of an iron cross T: see also *fig. 7*, fitted with a square upon the top of the spindle. On the lower part of the spindle the pinion Z, which gives it motion, is fixed: it has a square hole through it, fitting on the square spindle, and iron crosses are fixed both at top and bottom of the block of wood forming the body of the pinion: in this iron are two screws (see *fig. 8*.), which, being screwed fast, fix the pinion firmly to the spindle, its weight being supported by a wedge, *w*, put through a hole in it; but when this wedge is withdrawn, and the screws slackened, the pinion falls down so low upon the spindle, that its teeth are clear of the teeth of the cog-wheels *k*, *fig. 2*, and in this state the spindle and mill-stone upon it will stand still, though the mill is going. The spindle foot, *s*, rests in a brass socket, fixed in a lever *w*, *figs. 1 and 2*, called the bridge-tree: its fulcrum is in the solid wall, W, *fig. 1*, at one end, and the other rests on the middle of a second lever X, perpendicular to the former, called the brayer, one end of which has a fulcrum in the framing, *fig. 2*, and the other is supported by a screw, which the miller turns round, to elevate or depress the upper stone, and adjust the distance between them at pleasure, according as he wishes to grind finer or coarser flour. The upper part of the mill before us is used as a store-house for corn, which is drawn up in sacks by the tackle into the roof, and there emptied into bins, or different compartments, of the upper floor: from these it is let down to the mill-stones, and ground into meal. The spouts from the stones lead the meal into sacks, which, when full, are drawn up to the top of the house again, and emptied out into a flour bin, situated over the dressing machine M, which separates it into various qualities for use.

The mills which grind for the London market use three dressing machines: the finest flour is that which has been passed through a wire-cloth of 64 *per* inch, when the meal is dressed the first time; the other part of the cylinder is coarse wire, which suffers a coarse meal, called middlings, to pass through it; but the bran and coarse pollard fall out at the end of the cylinder. The middlings are ground over again in a pair of mill-stones, which are rather dull, and become unfit for grinding corn, without dressing them again: then, after this second grinding, the meal is dressed in the cloth machine, called the bolting cloth, which takes out the second flour, and the pollard comes out at the end of the cloth: the bran and the pollard together are now put into the clearing-off machine, which is a coarse wire-cylinder of the kind we have described, and by it is separated into hog pollard, which is the finest sort; 2d, horse pollard; and, 3d, bran. A pair of mill-stones will grind five bushels of wheat *per* hour, when in good condition; but require to be taken up and dressed once a week, if used constantly. This dressing is done by picking the surface of the stone over with the mill-pick, to cut the grooves and furrows sharp, that they may grind and cut the corn between them.

Persons riotously assembling and destroying, or maliciously burning, any wind-faw mill, wind-mill, or water-mill, &c. shall be guilty of felony, without benefit of clergy, by 9 Geo. III. c. 29. Prosecution to be commenced within eighteen months after the offence committed. By 41 Geo. III. c. 24. the damages occasioned by demolishing any such mill by persons riotously assembled, may be sued for and recovered in the manner provided for by 1 Geo. stat. 2. c. 5. respecting the demolishing of churches and other buildings. (See R107.) By 43 Geo. III. c. 58. any person who shall maliciously set fire to any mill in the possession of any other person, or of any body corporate, shall be guilty of felony, without benefit of clergy.

Water-mills have long been great nuisances to agriculture, by preventing the use of the streams on which they stand, in many cases, in irrigating and flooding the adjoining lands, by which much improvement is kept back, that would otherwise take place. They are also injurious by obstructing and damming up the water in numerous instances, so as to render it stagnant on the ground above. Wind and steam may, however, be applied as the moving powers of mills without producing any such effects, and are, of course, the most proper powers to be employed.

The ancient feudal custom of obliging tenants to grind at the lord's mills, is now almost wholly done away. Draining or lifting-mills are often extremely useful in discharging water from low flat lands in many situations. The moving power in these is commonly wind. See MILL, in *Mechanics*.

By an ancient ordinance the toll for grinding shall be taken either to the 20th or 24th corn; and yet, in some places, millers claim and take the 16th part: but Mr. Dalton says, that the miller should take but one quart for grinding one bushel of hard corn, and if he carry back the grist to the owner he may take two quarts of such corn, *i. e.* wheat rye, and meslin, (wheat and rye mixed.) For malt he shall take half as much as for hard corn. By Holt ch. just. the toll of a mill must be regulated by custom, and if the miller take more than the custom warrants, it is extortion: but if it be a new mill, the miller is not restrained to any certain toll. (1 L. Raym. 149.) In some places the tenants are bound to have their corn ground at the lord's mill. When a miller, upon information given on oath to any magistrate, is suspected of adulterating meal or flour, the house, mill, &c. of such miller may be entered under the authority of a warrant of a magistrate, at all reasonable times of the day, to search for discovery, and if such adulterated meal or flour be found, it may be seized by the officer executing the warrant, seized by the magistrate to whom it is carried, and disposed of at his discretion. (31 Geo. III. c. 29.) A miller who hath corn given him to grind, and who charges for that which is bad, is indictable; and he may be guilty of felony by taking away any part with an intent to steal it. (Hawk. c. 33.) Millers are not to be common buyers of any corn, with a view to sell the same again, either in corn or meal. (Dalt. c. 122.) By 36 Geo. III. c. 85, every miller shall keep balances and weights according to the standard of the exchequer, which may be examined by a person appointed for this purpose by 35 Geo. III. c. 102; and in default thereof the miller shall forfeit not exceeding 20s. &c. &c. Millers may be required to weigh corn, and, on refusal, shall forfeit not exceeding 40s. Millers are to deliver the whole produce of corn when ground, if required, allowing for waste in grinding and dressing, and for toll when taken; and if such

corn shall weigh less than the full weight, such miller shall, for every bushel of corn deficient in weight, forfeit not exceeding 1s. and also treble the value of such deficiency. When toll is taken, it shall be deducted before the corn shall be put into the mill. No miller shall demand corn for toll, but in lieu thereof shall be entitled to payment in money, under penalty of forfeiting not exceeding 5l.: excepting when persons shall not have money to pay for grinding, and also, that this shall not extend to mills called "Soke-mills," or such ancient mills as are established by custom and the law of the land, which mills shall continue to take toll as they have been accustomed to do. Every miller is required to put up in his mill a table of the prices in money, or of the amount of toll or multure, on pain of forfeiting 20s. for every such offence.

MILLS, Wind, are, with respect to their working parts, little different from those of water-mills; but they are turned by the force of wind gathered in their sails.

Of these, some are called *vertical*, others *horizontal*, according to the position of the sails; or, rather, according to the direction of their motion, with regard to the horizon.

For the best form of horizontal sails, and also for determining the position of the axis of wind-mills, see *WIND-mill* and *MECHANICS*.

MILLS, Portable or Hand, are those kept in motion by the hand; or else whose mill-stones are turned, or pistons driven by the force of horses or other beasts. Thus, if the cog-wheel D, (*Plate XXXIII. Mechanics, fig. 1.*) be made about eighteen inches diameter, with thirty cogs, the trundle as small in proportion, with ten staves, and the mill-stones be each about two feet in diameter, and the whole work be put into a strong frame of wood, as represented in the figure, the engine will be a hand-mill for grinding corn or malt in private families. And then it may be turned by a winch instead of the wheel A A; the mill-stone making three revolutions for every one of the winch. If a heavy fly be put upon the axle B, near the winch, it will assist greatly in regulating the motion.

If the cog-wheel that turns the trundle or trundles of a mill be placed horizontally, horizontal levers may be fixed into its vertical axis, and horses applied to these for turning the mill; which is often done where water cannot be had for that purpose.

The use of mills and mill-stones, according to Pausanias, was first invented by Myla, son of Meleges, first king of Sparta; though Pliny attributes the invention of every thing belonging to bread and baking, to Ceres: Polydore Virgil was not able to discover the author of so useful a machine. It is doubted whether or not water-mills were known to the Romans, there being no mention made, in the Digest, but of mills turned by slaves and asses. Salmasius, however, and Gothofred, will not allow water-mills to have been unknown to the ancient Romans, though they were not in ordinary use. Wind-mills are of much more modern invention; the first model of these was brought from Asia into Europe in the time of the holy wars.

MILL is also used for any machine, which being moved by some external force, serves to give a violent impression on things applied to it.

Mills, in this sense, are machines of vast use in the manufactures, arts, and trades; for the making and preparing divers kinds of merchandizes. The principal are those which follow.

MILL, Colour. Colours for the use of painters, paper-

stainers, &c. are prepared, in the large way, by grinding them, either with oil or water, in mills worked formerly by horses, but now frequently steam-engines are used for such purpose in London. These colour-mills consist of a large toothed-wheel, or cog-wheel, worked by the horses, or steam-engine, &c. which gives motion to several trundles and upright spindles of small mill-stones placed round its circumference. The construction and use of these will be readily comprehended from the following description of a single pair of stones to be worked by hand, *Plate XXXV. fig. 1.* The winch-handle A gives motion, by the labour of a man, to the spindle B and fly-wheel C, fixed thereon; and which also carries a small spur-wheel D, having eighteen bevelled teeth, which work into those of the crown-wheel E E, of twenty-six teeth, fixed upon the upright spindle F, working in a brass collar at top, fixed to the piece of wood G, which is adjustable by means of the wedge H, so as to keep the teeth of the wheels properly in gear: the bottom of the spindle works in the end of a brass screw R, working in the bottom framing of the machine, and passing up through the centre of the lower stone, the turning of which screw, occasionally, adjusts the distance of the stones, which are of the common construction, exactly like those for grinding flour, but smaller, each being sixteen inches diameter and three inches thick. The upper stone I is supported on the upright spindle F by a shoulder and crow, the same as mill-stones in general; it has a hopper K affixed to it, and which revolves with it, into which the semi-fluid colours intended to be ground are put, and when ground they are protruded through a spout from the tub M, nineteen inches diameter, which contains the stones.

After the above process, colours for the use of painters, &c. were ground by hand with oil or water, on a polished marble slab with a pebble muller; but this process being tedious and expensive, as well as highly prejudicial to the health of the workman, Mr. James Rawlinson of Derby, some years ago contrived a mill for this purpose, which is represented in *fig. 2*, a model of which he presented to the Society of Arts in the Adelphi, London, in 1804. A is a roller or cylinder of black marble, truly formed and well polished, 16½ inches diameter and 4½ inches broad; B is a concave muller, covering one-third of the roller, of the same kind of marble, well polished, and fixed in the wooden case or frame b, which is hung on hinges at i, for use when the muller requires to be lifted off the cylinder. C is a crooked bar of iron, about an inch broad, moveable on a pin at f, in order to turn down out of the way when the muller is to be lifted off: near the end of this bar is a thumb-screw c, whose end acts in a hole in the wooden case b, and serves to keep that and the muller steady, and to increase the pressure of the muller as occasion may require. D is a scraper or taker-off, made of a piece of clock-spring fixed in an iron frame K, in the manner of a frame-saw, and turning on centres d d, so that when in use the taker-off lies in an inclined position against the cylinder, and at other times is turned back out of the way. H is a plate set under the taker-off to catch the colour when sufficiently ground, which stands upon a sliding board that can occasionally be drawn out, to remove any colour which may accidentally drop from the cylinder. F is a drawer under the mill for holding curriers' shavings, for cleaning the cylinder and muller, when a fresh colour is wanted to be ground. The colour, roughly ground in a large colour-mill above described, is applied in proper quantities, by means of a knife, to the front of the cylinder above the taker-off, and by means of the winch-handle G the mill is worked, until the colour, by passing between the revolving

stone and muller, is sufficiently ground; when the taker-off D, which during the operation lay back, is turned against the stone, the winch-handle is turned the reverse way for a few revolutions, in order to scrape off the colour which falls into the dish H.

In the Philosophical Transactions, No. 87, a mill is described as having been used by Dr. Langelot, for grinding leaf gold to powder, for the fanciful purpose of preparing *Aurum potabile*: the principles of this mill were, some years ago, found applicable to the grinding of dry indigo in Mr. Taylor's manufactory at Manchester, and were also found by Mr. Rawlinson, above mentioned, to be the best adapted for finely pulverizing the dry colours intended to be ground with oil or water in his colour-mill. This simple mill is represented in *fig. 3*, where L is a marble mortar, nicely formed and polished; M is a muller nearly in the form of a pear, having an iron axis fixed into its upper end, which is bent into the form of a crank at P to serve as a handle for turning the muller: the axis is fixed, when in use, into two collars O, O, in beams of wood NN, so as to revolve easily and truly in the axis of the mortar. This muller is shewn separately at *fig. 4*, which shews a slit that is made through it, almost dividing it into two parts: this slit is of use in collecting the colour which is grinding, and bringing it continually under the muller. A circular board in two halves, with a centre-hole to fit the axis, is used to lay over the mortar, to prevent the dust of the colours from flying out, to waste the same and injure the health of the workmen. By means of the flat perforated weights R, on the top of the axis, any required pressure can be applied upon the muller.

For preserving the health of such colour-men and painters as still prefer the common stone and muller for grinding their colours, M. Boulard, in the *Journal de Physique*, recommends an apparatus represented in *fig. 5*, wherein the stone, and its table A B, is surrounded by a close-sided casing of boards C, C, fitted to the floor of the room, and leaving a space of about $\frac{1}{2}$ th of an inch wide all round the table supporting the stone; this is for emitting a current of fresh air, which is to be supplied by a pipe D D extending from a hole in the floor under the case, to the outward air in some most convenient place. Over the stone a glazed pyramid E E and metal tube F is supported by the irons G and braces H, H, H, or by other more convenient means, so that the pyramid E E projects, on all sides, about three inches beyond the stone; and at a height above the same no greater than is sufficient for the free admission of the workman's arms to work the muller, and with his pallet knife to scrape together the colour when requisite, and which he will be able perfectly to see to do, through the glass in the frame, without inhaling the vapour from the colours, but which are to be made to ascend through the tube F, and pass off into the open air through the tube M M, by means of a small stove I I closely jointed to the tubes F and G, which is to be kept burning during the hours of work, in order to produce a current between the pipes D and M, that may effectually carry off the contaminated air which has been in contact with the colours on the stone, along with their effluvia. K represents the door of the fire-place, and L that of the ash-hole of the stove, both contrived to shut very close. In the pipe F a register N should be made for regulating the burning of the stove, by the admission of more or less air thereto through the pipe F. If desirable, the close pipe F may be conducted into the fire-place of any stove or fire in the apartments above, or it may even descend by a proper curvature, so as to admit of the stove I I being placed on the ground, and applied to any useful purpose, as the boiling of oil, or heating an adjoining room, &c.

MILL, Cotton. See MANUFACTURE of Cotton.

MILL, Flood, that sort of mill which is contrived for the purpose of raising water in order to discharge it from fens, marshes, and other similar kinds of land.

MILLS, Forge, turned by water, serve to raise and let fall one or more huge hammers, to beat and form the iron into bars, anchors, and other massive works. They are also called tilt-mills. See FORGE, IRON, and STEEL.

MILL, Fulling, is a water-mill which raises and bears down large wooden pistons in proper vessels called *pools*, or *troughs*; in order to full, scour, and cleanse woollen stuffs. See FULLING-Mill.

MILL, Gunpowder, is that used to pound and beat together the ingredients whereof gunpowder is composed.

This is done in a kind of iron or brass mortar, by means of iron pestles wrought by a wheel without side the mill, turned by the water falling on it. See GUNPOWDER.

MILLS, Leather, are used to scour and prepare with oil, the skins of stags, buffaloes, e.ks, bullocks, &c to make what they call *buff-leather*, for the use of the soldiery.

This is effected by means of several large pistons, rising and falling on the skins, in large wooden troughs, by means of a wheel without-side, turned by the force of water.

MILLS, Linen, do not differ much from fulling-mills. Their use is, to scour linens, after their having been first cleansed when taken out of the lixivium, or ley. Some of these go by water, and the generality by horses.

MILLS, Oil, when turned by men, water, hand, or horse, serve to bruise or break the nuts, olives, and other fruits and grains, whose juice is to be drawn, by expression, to make oil. See OIL.

MILL, Paper, a water-mill, furnished with engines containing cylinders furnished with teeth which cut and grind the rags or cloth in a kind of wooden trough; and thus, by reducing them to little pieces, turn them into a kind of pulp, by means of water conveyed into the troughs by a pipe for that purpose. See PAPER.

MILL, Sawing, is a water-mill, serving to saw several planks or boards at the same time.

These are frequent in France, especially in Dauphiné.

They were lately prohibited in England, where they were begun to be introduced, from a view to the ruin of the sawyers, which must have ensued. See SAWING, also MACHINERY, Block.

There are also *filk* mills, for spinning, throwing, and twisting silks; which are large round machines in form of turrets, five or six feet high, and six yards in diameter; which, being turned, either by the force of water or that of men, work at the same time an infinity of bobbins fastened thereto, whereon the silk had been wound to be here spun and twisted.

There are abundance of mills of this kind in France, especially about Lyons and Tours, some of which are so disposed, as that three of them will go at the same time, and by the same wheel wrought by water or by strength of hand. That in the Hôpital de la Charité at Lyons, is wonderful, a single man working no less than 48 of these mills. See SILK, and WINDING of Silk.

MILL, Stamping. See STAMPING.

MILL, Sugar, is a machine that serves to bruise the sugar-canes, and express the liquor or juice contained therein. The sugar-mills are very curious contrivances. Of these there are four kinds, being turned either by water, wind, men, or horses.

Those turned by the hand were first in use; but they are now laid aside, as being an intolerable hardship on the poor

negroes who were doomed thereto, besides the slowness of their progress.

Wind-mills are the most modern: but they are yet somewhat rare, excepting in St. Christopher's and Barbadoes, and among the Portuguese. These make good dispatch, but have this inconvenience, that they are not easily stopped; which proves frequently fatal to the negroes who feed them. See SUGAR.

MILLS, *Tan or Bark*, wrought by water or horses, serve to cut certain barks into a coarser sort of powder, proper for the tanning of hides, &c.

MILLS for *Sword blades* are likewise moved by water. They are frequent at Vienne, in Dauphiné. By working heavy hammers they forge those excellent sword-blades, called *blades of Vienne*.

The uses and operations of these several mills, more at large, see under PAPER, FULLING, SUGARS, &c.

MILL, *Threshing*, such a machine as is contrived for the purpose of threshing grain or other sorts of seed crops. See THRESHING Machine.

MILL, in *Coinage*, is a machine used to prepare the laminæ, or plates of metal, and to give them proper thickness, hardness, and consistence, before they be struck, or stamped.

This machine has not been long known among us; but is of some standing in Germany. It consists of several wheels dented like those of clocks, &c. which move two cylinders of steel, between which the metal is passed to be brought to its proper thickness. It was first turned with water, since with horses. See COINAGE.

MILL, in *Commerce*, a money of account in the United States of America; 1000 mills being = 100 cents = 10 deniers = a dollar.

MILL, among *Gold Wire Drawers*, is a little machine consisting of two cylinders of steel, serving to flatten the gold or silver wire, and reduce it into laminæ, or plates. See GOLD Wire.

They have also mills to wind the gold wire or thread on the silk: these are composed of several rows of bobbins all turned at the same time.

MILL-*Reek*, in *Medicine*, an appellation given by the miners, employed at the Leadhills in Scotland, to those affections of the bowels, and of the nervous system, which are occasioned by the poison of the lead. The melting-houses, in which the operations are carried on, are called *mills*, because the bellows there are worked by water-wheels; and the *reek*, or smoke, arising from the melted lead, is believed to be the chief cause of the disease: whence the term *mill-reek* has been appropriated to the malady. See ESSAYS and OBS. Phys. and Liter. vol. i. art. xxii. Edinburgh.

MILL-Dams, in *Rural Economy*, the basons which contain the water for supplying mills. A very firm way of making these in a quick or running sand, which is usually found a very troublesome circumstance in the making of them, is by laying the foundation with unslaked lime; which, by slaking among the sand, runs together into a hard stone, which gives a very firm and sure foundation. Piott's Staffordshire, p. 336.

MILL-Holms, a term applied to the low meadows, and other fields in the vicinity of mills, or watery places about mill-dams. The soils in these cases are generally of a good quality.

MILL-Pool, a stock or pond of water, by the force of which the motion of a water-mill is effected.

The dam of a mill-pool is raised much in the same manner as directed for *fish-ponds*; which see.

MILL-Stones, in *Rural Economy*, the prepared stones made use of in grinding grain and other substances, which are of

different kinds, according to the purposes for which they are employed, but those chiefly used in grinding wheat into flour, were formerly imported from France, and termed *burræ*. Lately, however, stones proper for this use have been discovered in different parts of this kingdom, as in Wales and Scotland. In the first of these places they were found by Mr. Bowes, in a quarry which is "situated within the corporation liberties of Conway: the stone appears within a quarter of a mile of that town, and extends from east to west for the distance of two miles, appearing in most places upon the surface within that distance. Such an immense body of the stone has been left bare and exposed to view, that the industry of ages would scarcely lessen it. A deep chasm intervenes at the end of two miles; and, on examining the same line across this valley, he found the stone mixed up with various other fossil substances, to which it seems to bear no relation. In the next rise of mountains it resumes its quality, and takes a southerly direction, passing through a range of hills to the distance of two miles more, where the vein disappears. It is every where the highest stratum; and when disengaged from the quarry where now worked, it tumbles down the side of the mountain to the plain within five hundred yards of the shipping-place, where small vessels may lie safely in all weathers at a natural quay, completely calculated for this business." The quarry lies on the decline of a hill: the vein now is about eight yards wide; but he has reason to suppose it wider below. At the depth he has sunk, which is at least twenty-five feet, the stone mends in quality. When first taken from the quarry it is much softer and easier wrought into shape, than when exposed to the air: even a day makes a difference. The vein appears to him quite inexhaustible, and contains every variety of the stone, cellular, close, hard, or soft. The right in this tract of country has been presented to him, by Mr. Sneyd of Staffordshire, under the hope that he might be able to make this discovery, and carry it vigorously into effect, in which he has not been disappointed.

It would appear from the evidence sent to the Society for the Encouragement of Arts, &c. that the stones raised from this quarry are capable of being employed in most cases where those imported from France have been in use, and that the stone, from its external appearance, seems to be constituted of quartz and cherts.

And in the latter of the above situations stones fit for this use were discovered by James Brownhill, miller, "who, when the late unfortunate war had rendered the getting of the French burr extremely difficult, as he was passing by the great basaltic rock of the Abbey Craig, near Stirling, examined the texture of several masses of the stones; and found one species, which appeared to him fit for the grinding of wheat, and brought home a sample of them, which he shewed to Mr. Alexander Ball, agent of the Alloa Mills, who agreed to make trial of a pair. They were built under his direction in the same manner as the French burr; and, on their being put to work, gave such satisfaction to the customers of the mills, as induced the Alloa Mill company to have another pair built, and totally lay aside the French burr mill-stones." It is suggested, that "the French burr stones are so porous, as to make it necessary to fill up the cavities with a preparation of alum: this considerable expence is saved by the uniform texture of the basaltes; and their superior excellence is so apparent, that upwards of 60 pair are now at work in several parts of the kingdom, and the demand for them is daily increasing." In addition it is stated, that "the basaltes mill-stones are not only excellent for manufacturing of flour, but for all kind of grist. The distillers give them a decided preference, and they grind oats

in a very complete style, as the meal is returned quite free of sand, which is a great desideratum for those places where oat bread is in use. The discoverer of this use of the basalt, builds mill-stones of all sizes on moderate terms, and is careful, from his experience as a miller, to build them of such a grain as is most suitable for the particular purposes for which they are intended.

The following remarks are offered by Mr. Ferguson on the size and velocity of mill-stones. The diameter of the upper stone is generally about six feet, the lower stone about an inch more; and the upper stone, when new, contains about $22\frac{1}{2}$ cubic feet, which weighs somewhat more than 19,000 pounds. A stone of this diameter ought never to go more than 60 times round in a minute; for if it turns faster, it will heat the meal. But according to Mr. Imison, the mill-stone should turn twice round in a second of time, and should only be four feet and a half in diameter. It may probably be imagined, that the meal will be much heated by such a rapid motion as he has recommended, but the effect is counteracted by diminishing the size of the mill-stone from six feet to four and a half. The velocity of the circumference of the small mill-stone moving twice round in a second, is only one-third greater than the velocity of the large mill-stone moving once round in a second.

It may be noticed, that in the former of the above quarries mill-stones are raised which are of much larger sizes than the French burrs, which may probably be an advantage in some cases.

The modes of preparing mill-stones for the purpose of grinding have been described already, and *fig. 6. of Plate XXXV.* represents the surface of the under grinding mill-stone, the way of laying out the wads or channels: the wooden bush is fixed into the hole in the middle, in which the upper end of the iron spindle turns round; and the case or hoops that surround the upper one, which ought to be two inches clear of the stone all round its circumference. B shews the upper grinding mill-stone, and iron cross or rynd in its middle, in the centre of which is a square hole that takes in a square on the top of the iron spindle, to carry the mill-stone round: when the working sides or faces of the mill-stones are laid uppermost, the wads must lie in the same direction in both, that when the upper stone is turned over, and its surface laid on the under one, then the channels cross each other, which assists in grinding and throwing out the flour; the wads are also laid out according to the way that the upper stone revolves. In these the running mill-stone is supposed to turn *sunways*, or what is called a right-handed mill; but if the stone revolves the other way, the channels must be cut the reverse of this, and then it is termed a left-handed mill. See *MILL*.

The mill-stones which we find preserved from ancient times, are all small, and very different from those in use at present. Thoresby mentions two or three such found in England, among other Roman antiquities, which were but twenty inches broad; and there is great reason to believe that the Romans, as well as the Egyptians of old, and the ancient Jews, did not employ horses, or wind, or water, as we do, to turn their mills, but made their slaves and captives of war do this laborious work; they were in this service placed behind these mill-stones, and pushed them on with all their force.—Sampson, when a prisoner to the Philistines, was treated no better, but was condemned to the mill-stone, in his prison. The runner, or loose mill-stone, in this sort of grinding, was usually very heavy for its size, being as thick as broad. This is the mill-stone which it is expressly prohibited in Scripture to take in pledge, as lying loose it was more easily removed. The Talmudists have a story,

that the Chaldeans made the young men of the captivity carry mill-stones with them to Babylon, where there seems to have been a scarcity at that time; and hence, probably, their paraphrase renders the text "have borne the mills, or mill-stones;" which might thus be true in a literal sense. They have also a proverbial expression of a man with a mill-stone about his neck; which they use to express a man under the severest weight of affliction. This also plainly refers to this small sort of stones.

MILL-Work. Under this head we intend to treat of the parts and mechanical contrivances used in mills. Under the article *MACHINERY*, the reader will find observations of a similar nature to those of the present article, but applied to smaller and more delicate machines than those which are usually denominated mills.

The object of this article will therefore be, to give a general account of the most important pieces of mill-work, as cog-wheels, shafts, bearings, &c.; which parts being common to mills of all kinds, would, if minutely described under every head where they are employed, introduce a great many needless repetitions.

The different first movers of mills will be treated of, and described under their several heads of *STEAM-Engine*, *WATER-Wheels*, and *WIND-Mill*; and the acting machines of several kinds of mills, as clay-mill, grinding-mill, under *CUTLERY*; fulling-mill, flour-mill, iron-mill, under *MANUFACTURE of Iron*; oil-mill, cotton-mill, under *MANUFACTURE of Cotton*; rolling-mill, spinning-mill, silk-mill, thrashing-mill, water-mill, sawing-mill, under *MACHINERY for manufacturing Ships' Blocks at Portsmouth*; *TILT Mill*, &c. &c.

Cog-wheels are the most important and numerous parts of mill-work, few mills being without them, to modify the direction, and adapt the power of the first mover, which actuates the mill, to the working point, or the machine which performs the operations the mill is intended for. Most mills contain several different kinds of machines, or operative parts, all deriving their motions from the same source, or first mover. Thus, a flour-mill contains stones for grinding; dressing machines for sifting the flour; sack tackle, for drawing up the sacks, &c.; all which are moved by the same first mover as a water-wheel, wind-mill, steam-engine, or horse-wheel. But each of these machines requires to be moved with a different velocity to perform its work in the best manner; and it is the object of the mill-work to obtain these different velocities from the same first mover, chiefly by the means of wheels; which, therefore, from their importance, deserve the first notice. There are a variety of cog-wheels, as spur-wheels, (or *gear* in the technical phrase,) bevil-wheels, face-wheels or crown-wheels, pinions or nuts, trundles or lanterns; with a variety of other names which are local, but have the same signification with some of the above.

Spur-wheels are those in which the teeth project from the periphery of the wheel, in the direction of radials (see *Plate I. fig. 1. of Mill work*): they are so called, from the resemblance to the rowel of a spur. A spur-wheel is used to communicate motion by its teeth to another, situated in the same plane; consequently, the axes of the two are parallel to each other. The spur-wheel, at other times, works with a *pinion*, or nut (see *fig. 2.*), which is in fact a spur-wheel of small size: at other times with a *trundle* or *lantern*. This is a pinion of peculiar construction; consisting of two circular boards *A, A*, (*fig. 3.*) fixed, at some distance apart, upon its axis of motion or shaft *B B*, and united by a number of cylindrical pins *a, a*, called *staves*, or *rounds*, which are arranged in a circle, and fixed parallel to the axis of the trundle between the two boards of it. The teeth of the wheel

set upon these rounds to give motion to the trundle; the rounds, therefore, must be the same pitch or distance asunder as the cogs of the wheel. The number of the rounds of the trundle of course determine its diameter. Trundles have of late years fallen into disuse among mill-wrights, cast iron pinions being found much more preferable: they were sometimes used to work with spur-wheels, but more commonly with

Face-wheels, see *fig. 4*. In these, the teeth or cogs are fixed perpendicularly to the plane of the wheel, parallel, therefore, to its axis: they were used to work with another similar wheel, or with a trundle with a spur-wheel, or with a pinion, when the two axes were required to be perpendicular to each other, as shewn in *figs. 3* and *4*.

The crown or face-wheel has of late years been almost wholly superseded by bevil-wheels, which, in all situations where a wheel is required to turn another in a direction perpendicular or inclined to itself, are found vastly superior.

Bevilled or Mitre-wheels, see *fig. 5*. of the plate, have their teeth formed upon a conical surface, the angle of the cone being the same as the angle the axes *C, D*, of the two wheels *A, B*, make with each other. The introduction of this class of wheels into machinery is a very essential improvement, which has been wholly made within these thirty years. Bevil-wheels are of course always used to work with others of the same kind.

The manner of setting out the teeth of cog-wheels, in such a form that they shall act in the most equable manner upon each other, and with the least friction, has been a subject of much investigation among mathematicians and theoretic mechanics; but the practice and observation of the mill-wrights have produced a method of forming cog-wheels, which answers nearly, if not fully as well in practice, as the geometrical curves which theory has pointed out to be the most proper. This they have effected by making the teeth of the modern wheels extremely small and numerous. In this case, the time of action in each pair of teeth is so small, that the form of them becomes comparatively of slight importance; and the practical method of the mill-wrights (using arcs of circles for the curves) approximates so nearly to the truth, that the difference is of no consequence: and this method is the best, because it so easily gives the means of forming all the cogs exactly alike, and precisely the same distance asunder, which, by the application of any other curve than the circle, is not so easy. The method, which is extremely simple, is explained by *fig. 1*. The wheel being made, and the cogs fixed in much larger than they are intended to be, a circle, *aa*, is described round the face of the rough cogs upon its *pitch diameter*, that is, the geometrical diameter, or acting line of the cogs; so that when the two wheels are at work together, the pitch circles, *a, a*, of the two are in contact. Another circle, *bb*, is described within the pitch circle for the bottom of the teeth, and a third, *dd*, without it, for the extremities. After these preparations, the pitch circle is accurately divided into the number which the wheel is intended to have: a pair of compasses are then opened out to the extent of one and a quarter of these divisions, and with this radius arcs are struck on each side of every division, from the pitch line *a* to the outward circle *dd*. Thus, the point of the compasses being set in the division *e*, the curve *fg* on one side of the cog, and *no* on one side of the other, are described; then the point of the compasses being set on the adjacent division *h*, the curve *lm* is described. This completes the curved portion of the cogs *e*, and this being done all round completes every tooth: the remaining portion of the cog within the pitch circle, *a*, is bounded by two straight lines drawn from the points *g* and *m* towards the centre;

this being done to the cogs all round, the wheel is set out and the cogs, being dressed or cut down to the lines, will be formed ready for work, every cog being of the same breadth; and the space between every one and its neighbour is exactly equal to the breadth, provided the compasses are opened to the extent of one division and a quarter, as first described.

Many different methods of forming teeth have been proposed, among them the following: Let the tooth *a* (*fig. 6*.) press on the tooth *b* in the point *C*; and draw the line *F C D E* perpendicular to the touching surfaces in the point *C*; draw *A F, B E*, perpendicular to *F E*, and let *F E* cut the line *A B* in *D*. It is plain from the common principles of mechanics, that if the line *F E*, drawn in the manner now described, always pass through the same point *D*, whatever may be the situation of the acting teeth, the mutual action of the wheels will always be the same. It will be the same as if the arm *A D* acted on the arm *B D*. In the treatises on the constructions of mills, and other works of this kind, are many instructions for the formation of the teeth of wheels; and almost every noted mill-wright has his own nostrums. Most of them are egregiously faulty in respect to mechanical principle. Indeed, they are little else than instructions how to make teeth clear each other without sticking. Dr. Hooke was, we think, the first who investigated the form of teeth which procured this constant action between the wheels; and in a very ingenious dissertation, published among the Memoirs of the Academy of Sciences at Paris, 1668, this gentleman shews that this will be ensured by forming the teeth into epicycloids. Mr. Camus, of the same academy, has published an elaborate dissertation on the same subject, in which he prosecutes the principles of M. De la Hire, and applies it to all the varieties of cases which can occur in practice. There is no doubt as to the goodness of the principle, and it has another excellent property, "that the mutual action of the teeth is absolutely without any friction." The one tooth only applies itself to the other, and rolls on it, but does not slide or rub in the slightest degree. This makes them last long, or rather does not allow them to wear in the least. But the construction is subject to a limitation which must not be neglected. The teeth must be so made, that the curved part of the tooth *b*, is acted on by a flat part of the tooth *a*, till it comes to the line *A B* in the course of its action; after which the curved part of *a* acts on a flat part of *b*, or the whole action of *a* on *b* is either completed, or only begins at the line *A B*, joining the centres of the wheels.

Another form of the teeth secures the perfect uniformity of action without this limitation, which requires very nice execution. Let the teeth of each wheel be formed by evolving its circumference; that is, let the acting face *G C H* of the tooth *a* have the form of a curve traced by the extremity of the thread *F C*, unrolled from the circumference. In like manner, let the acting face of the tooth *b* be formed by unrolling a thread from its circumference. It is evident that the line *F C E*, which is drawn perpendicularly to the touching surfaces in the point *C*, is just the direction or position of the evolving threads by which the two acting faces are formed. This line must, therefore, be the common tangent to the two circles or circumferences of the wheels, and will, therefore, always cut the line *A B* in the same point *D*. This form allows the teeth to act on each other through the whole extent of the line *F C E*, and, therefore, will admit of several teeth to be acting at the same time; (twice the number that can be admitted in Mr. De la Hire's method.) This, by dividing the pressure among several teeth, diminishes its quantity on any one of them, and, therefore, diminishes the dents or impressions which they unavoidably

make on each other. It is not altogether free from sliding or friction, but the whole of it can hardly be said to be sensible. The whole side of a tooth, three inches long, belonging to a wheel of ten feet diameter, acting on the tooth of a wheel of two feet diameter, does not amount to $\frac{1}{16}$ th of an inch, a quantity altogether insignificant. Conical wheels, or bevelled gear, may be considered as consisting of two cones rolling on the surfaces of each other: let B and C, (*fig. 7.*) be the bases of two cones turning on their centres, having teeth cut on them diverging from the apex A to the bases B and C. These teeth will work freely into one another from the apex A to the bases B and C, when turned round; but the teeth near the point of the cone being small and of little use, may be cut off at G and H. These teeth may be made of any breadth, according to the stress they are intended to bear; and this is of vast importance, because by this method they may be made to overcome a much greater resistance, and work smoother than a face-wheel and trundle of the common form. Besides, these kind of wheels are of singular use to communicate motion in any direction, or to any part of a building, with less trouble and friction than wheels of any other construction.

We shall now venture some remarks upon the manner of constructing wheel-work. Cog-wheels were formerly made of wood, and some are still constructed of that material; but of late years cast-iron wheels have been substituted, and found much superior in strength, accuracy, and durability. Wooden wheels are framed together in segments usually of three thicknesses, to break the joints upon each other. (*See fig. 1.*) The middle thickness is made in six or eight pieces, and left on the inside with straight sides, *x, x*, into which the arms are fitted, and bolted against it. On each side this middle thickness, another is (*XX, fig. 1.*) placed with break joints, and all the three are bolted together to make a solid rim, in which the cogs are to be fixed by mortises, the tenons or tails of the cog being held in their places by a pin driven through each. The arms of wooden wheels are made in different ways; sometimes they are mortised through the shaft, and the ends are notched in the middle of the sides of the octagonal pieces *x, x*, and laying against the face of them behind, are bolted to them to make all fast. This manner of uniting the arms with the rim is shewn at *l* (*fig. 4.*); but this method is not the best, because the mortises weaken the shaft very materially, and it is difficult to get such a wheel off if ever it is required, on a failure of the shaft, &c. On this account, the method called clasp arms is much preferable: it is shewn in *fig. 1.* Four arms *EE, FF*, are used, which are halved into each other, and form a frame as in the figure, leaving a square opening in the centre, and holding the rim of the wheel by their ends, which are bolted to the middle thickness of the rim, as shewn in *fig. 4.* To fit on such a wheel as this, the shaft is made up to a square, by fixing pieces of wood upon its sides; and the wheel being hung upon this, is made fast by wooden wedges driven in all round, the square formed between the arms being rather larger than the shaft, by which means the wheel can be adjusted to come quite true by the wedging. Face-wheels, like *fig. 4.*, have sometimes stays or braces proceeding from the back of the rim to some distance along the shaft, where they are received in mortises, as shewn by the dotted lines: these make the wheel exceedingly strong, and keep it very stiff in the square upon its axis, which is very necessary, as the action of the teeth of a face-wheel meeting a trundle, is to throw the wheel back upon its shaft, which tendency these stays effectually counteract. At other times, two sets of clasp arms are used for the same end, one bolted on each side of the middle thick-

ness of the wheel, by the same bolts which pass through both, as well as the wheel, and unite the two sets like one, but of considerable depth, so that the wedging will have a greater effect to keep the wheel in the square. Small wheels are frequently made of plank, solid, without any arms. In this case the middle thickness is made of four pieces, leaving a square hole between them, and they are kept together by a circular ring of segments, bolted on at each side all round, and the joints overlapped. The construction of trundles (*fig. 4.*) has been sufficiently explained, except that they usually have an iron hoop fitted round the circular boards to prevent them from splitting: indeed many large face-wheels have the same. Small pinions are made out of one block of wood, and the cogs are fitted into it much in the same manner as the spokes are let into the nave of a coach-wheel. Iron-wheels either have the cogs cast in the same solid piece with the rim, or mortises are left in the castings for the reception of wooden cogs, as these are found to work much better. The wheel and its arms are sometimes cast in one piece, but for large wheels the rim and its arms are formed in two separate pieces and screwed together. The reason of this is, that in casting a large and extended piece of iron, it frequently happens that some parts will cool in the mould, and become solid before the others: consequently, from their contraction, these parts will be shorter than others which have retained their heat and fluidity longer. This circumstance happening to the arms of a wheel, will either warp the rim out of a true circle, or set the metal of one part upon a strain against another, so that the slightest blow or jar will cause them to snap in such parts. All this danger is avoided by making them in separate pieces, as in *fig. 8*: the end of each arm, as *AB*, has a flat expanded part, which lays against a proper socket within side of the rim *CD*, and is bolted to it. One-half of this wheel is delineated, with wooden cogs fitted in, at *CD*; and the other half, *FF*, shews the form of a rim, where the cogs and the arms *ef* are cast all in one piece. In the latter case the rim has a rib *g* within side it for strength, in the same manner as all the arms have, and which is evidently shewn by the figure. In some situations it is necessary to fix wheels upon long shafts while they are in their places, and cannot conveniently be taken down: in this case such wheels may be made in two halves bolted together. *Fig. 9.* is drawn as if it were two halves of different kinds put together in this manner; the joint being up the middle of the arms *L, L*, and the connecting bolts are plainly shewn. By this method one wooden pattern, if very accurately made, will serve for casting both halves of the wheel. Cog-wheels are found to work with least friction, wear, or noise. When one has wooden, and the other iron cogs, dressed exceedingly smooth and true, the small wheel is usually made with the iron teeth, and the large one with the wooden ones. When such wheels are first set to work, the cogs are smeared with black lead mixed with tallow: this gives them a glossy surface, which greatly diminishes the friction. Hornbeam is found to be the best wood for the cogs, as it is not liable to split or splinter away by long wear. The cogs are held in by a pin driven through the tenon or tail, within side the rim of the wheel. The wooden cogs are dressed by chisels to the marks set out, in the same manner as wooden wheels; but the iron cogs are first chipped with a cold chisel and hammer, and then filed true. The great labour of doing this induced Messrs. Boulton and Watts, some years ago, to erect machinery for dressing cogs. The wheel was provided with apparatus to hold it fast at the several divisions, and a strong slider, with a chisel fixed in it, was forced between the rough cogs by the revolution of a cam or heart,

with a sufficient power to cut away a shaving, and form the cog perfectly at twice repeating the operation. Some mechanics dispute the propriety of dressing iron cogs at all; they say, that the exterior surface of the castings have a kind of case-hardening, which is removed by the dressing, and a softer substance of metal exposed for the acting surfaces. This is true, and the objection would have its full force, if it were possible to make castings of wheels perfectly true in the circle, and all the cogs precisely the same size: but as the present state of the founder's art cannot insure this, it is best to chip and file the cogs; accuracy in the form of the teeth being a superior consideration to any quality of their substance. The wheel being made in either of these methods, must next be fixed, or *hung*, upon its shaft. Wheels are generally fixed fast upon their shafts or axles before their teeth are set out; or, if this is not convenient, they are fixed on a temporary spindle to set them out. When the wheel is made of wood, it is fixed upon the shaft, or a temporary axis, and turned round upon its pivots, while a chissel is laid on some fixed support to cut or turn its circumference to a true circle, or else to make a mark to which its rim may be reduced all round. The circumference is then divided, and mortises cut out for every cog; and when these are fixed in they are much larger than they are intended to be, that they may be set out, as above directed, and reduced to their true figure, without absolutely depending upon the accuracy of the mortises which receive them. Iron wheels are, as before-mentioned, treated in a different manner, being cast in the impression of a truly circular pattern made of wood; the cogs cast solid, with the rim or else mortises left all round for the reception of the wooden cogs: in either case the rim is a true circle, and must be fixed upon the shaft exactly by its centre, instead of forming the circumference to the centre, as in the wooden wheel. To do this, the centre hole through the iron wheel is made much larger than the shaft which is to go through it, and the space all round is filled up by iron wedges driven in; so that by means of these the wheel can be fixed exactly true in the centre (or in the round), and also in the flat that is truly perpendicular to the axis. The manner of arranging the wedges is shewn in *fig. 8*, where eight wedges are shewn by *a, a, a, a, &c.* round the shaft *R*. It is needless to explain how the wheel can, by means of these, be set exactly true, when it is found by turning round upon the pivots of its shaft that any one side of the circumference is farther from the centre than another. For the purpose of setting it square upon the shaft, each wedge-hole is provided with two wedges, one driven in from each side of the wheel, the two laying over each other in the notch or hole in the manner shewn at *G*. Thus, by gently driving one in, and the other a little outwards, the wheel may be very correctly rectified, if it has any deviation from the perpendicular. This is the usual manner of hanging wheels, and for large wheels it is the only applicable method. *Plate II. figs. 9 and 10*, is a far superior plan for such iron wheels as are not too large or heavy to be turned in a lathe upon a chuck, so that the centre is exposed, and may be bored through with a truly circular hole, and rather conical: of course the wheel is fixed upon the chuck, so that its circumference runs truly; and at the same time the centre is bored, the pitch circle is described upon the cogs, and sometimes the ends of the cogs are turned to reduce them to a true circle, and also the sides, that they may be exactly flat: for, as we have before observed, iron wheels, however true their teeth may be cast, should always have their cogs rather too large, and then be set out and dressed, by chisseling and filing, to make them perfectly correct to the lines thus

described. But to return to *fig. 9*; the wheel being prepared, and its centre bored out, the shaft is turned, as usual, to form its pivots, and, at the same time, the part which is to receive the wheel is turned conical, to fit the hole through the wheel, which being jammed thereon will certainly be true at once: and to prevent it from slipping round upon its axis various means are in use; sometimes a mortise is formed through the shaft *A*, at the small part of the cone, and a wedge *r* driven through, which is received in notches at the sides of the hole through the central part of the wheel, so that it holds the wheel from turning round on the shaft, at the same time that it drives it hard, and fixes it upon the conical fitting. Another method is to cut a channel along the conical part of the shaft parallel to the axis of it, and another similar one within of the hole through the wheel; then a fillet or feather of iron *s*, (*fig. 10*.) being inserted into the two grooves, effectually prevents the wheel from turning, unless the strain is so great as to cut the feather in two through its whole length, which is easily prevented by making it of a proper thickness. Another method of fixing a wheel is to have a flanch, or flat shoulder, formed upon the shaft, and the wheel is drawn up against this by two, three, or four screw-bolts going through it, and also through the central part of the wheel, parallel to its axis. This plan is neither so neat, simple, nor strong as the former. When a wheel is required to be sometimes disengaged from its axis, the conical or cylindrical fitting is very convenient. In this case, the wheel should fit up against a flat shoulder, as *a*, in *fig. 11*, and at the opposite side should have a collet, or ring *b*, to confine it, and kept up by a key going through to the shaft *R*. In this way the wheel will slip round freely upon its axis, and communicate no motion thereto, though it is in constant motion itself: but when they are required to be connected, a locking bayonet, or clutch-box, is used. These pieces of mechanism are constructed in different forms; one of them is shewn in the figure. Strong arms *A, A*, are fixed fast on the shaft *R*, just before the wheel either by a circular fitting with a fillet, by a square, or they may be cast with it. Through the extremities of these arms holes are drilled to receive the shanks *f, f*, of the locking bayonet, which are fixed by nuts fast to an arm *D*, very nearly similar to *A, A*, but it slides on the shaft, and has a central part *g*, with a circular groove round it, in the manner of a pulley, and a fork embracing the central piece in this groove gives the means of sliding the bayonets *f, f*, and *D*, upon the shaft, so that the points of its shanks intercept the arms of the wheel, so as to carry it round with them and the shaft; but when the points of *f, f* are drawn back clear of the arms of the wheel, it slips round freely upon the shaft. The clutch-box is rather different from this; it is a piece fitted upon the shaft with a fillet, so that it cannot slip round, but will slide endways upon it. The end of the piece is formed with several notches, or indentations across its face, which meet similar indentations in the face of the central part of the wheel, and thus unites the wheel and the shaft when the clutch is slid up to it; but the wheel is disengaged when the clutch is drawn from it. The construction of *bearings* for the support of pivots at the ends of shafts or spindles, is a matter of great importance in mill-work. The old kind of bearing called *brasses* is shewn in *fig. 12*. A lump of brass *a*, with a semicircular notch in it, was let into the piece of timber *A*, which was to support it; and two screw-bolts *b, b*, were fixed through the timber, being half received in notches formed in the sides or ends of the brasses: the upper brass *b*, was exactly similar to the lower, and over it a plate of iron, *d*, was placed, with two holes through it to receive the two bolts *b, b*, and keep

them together: the nuts *c, c*, upon the tops of the bolts confined the upper brags down, and made all fast and tight. This kind of brags is not sufficiently strong or steady for all purposes, and, therefore, the bearing shewn in *fig. 13*. has taken its place: in this, *aa* is a cast-iron plate, which is held by two or more bolts *r, r*, down upon the timber or framing of the mill: this piece of cast-iron has two pieces *b, b*, rising up from it, between which a piece of brags, *l*, is bedded, and has a semicircular notch in it. Another similar piece of brags is fixed into the cast-iron cap-piece *B*, which is fitted into the space between the two pieces *b, b*, and is drawn down by nuts upon the two bolts *c, c*. The brasses are prevented from getting out sideways by small fillets projecting from the middle of them, which are received into proper notches in the cast-iron work. In the same manner the cap *B* is fitted between the pieces *b, b*, with a tongue or fillet, and groove, so that it cannot deviate sideways, and then the bolts have only to draw the brasses down together. Sometimes a bearing of this kind is fitted up, so that it is adjustable in its position a little to adjust two wheels to work accurately with each other, or for other purposes where nicety is required. In this case, an iron plate, *D*, is bolted down to the framing, and the bearing, *aa*, lays upon it, the same bolts *r, r*, going through both, and also through the framing beneath; but the holes through which they pass in the piece *aa* are oblong, to admit the whole bearing being adjusted sideways. This is done by two wedges *o, o*, inserted at the ends of the piece *aa*, between the two ends of *D*, which rise up for the purpose, as at *nn*. The bearing rests upon two wedges at *g, g*, and is drawn down upon them by the bolts *r, r*. By these two wedges it can be raised up at pleasure, and by the other two, *o, o*, at the ends, it can be adjusted endways to set the bearing in the exact position required; and the bolts *r, r*, when screwed fast, hold all tight. The best way to make the interior surface of the brasses for a bearing exactly true, is to have them cast solid, that is, the two halves of the brags in one, with a notch which very nearly, but not quite separates them. In this state it can be chucked in a chuck-lathe, and the inside bored or turned out true: then it may be sawn in two halves, and put into its place, to which it should have been previously fitted. Sometimes the bearing is all fitted together and screwed down in its place, and a borer is used to bore or broach out the hole for the brasses, the same as is employed to bore pump barrels. Brags is found, by experience, to be the best substance to form bearings for a cast-iron gudgeon, having the least friction, and, consequently, least wear, of any other substance which can be used. To diminish this friction still farther, friction-wheels are sometimes used. The manner of constructing these, when merely required to support a gudgeon, leaving its own weight to keep it down in its place upon them, is shewn in *fig. 14*. Here *AA* is an iron plate, which is to be bolted down upon the framing: it has holes through it to receive the friction-wheels *B, B*, and supports bearings *a, a*, for their pivots raised up to a proper height, and provided with sockets for brasses, in which the pivots of the friction-wheels are to lie. The two friction-wheels *B, B*, as is evident, lie by the side of each other, and the gudgeon, *D*, of the shaft they are to bear lies upon and between them, so that when it turns round it rolls upon them, or rather, their circumferences move with it, and, consequently, the pivots of the friction-wheels move so slowly, as to diminish the friction very materially, the proportion depending on the relation between the diameters of the wheels *B* and the gudgeon *D*. This is not the best kind of friction-wheels, though the simplest. *Plate II. fig. 15. of Mill-work*, contains a view of another kind, called

friction-rollers: here *AA* is an iron plate bolted down to the framing, and an iron ring, *B*, rises up from it, all cast in one piece. The interior surface of this ring is turned in the lathe with the greatest accuracy, and the pivot or gudgeon *C*, which is also turned true, rests in the centre thereof, being supported by six rollers *a, a*, &c. arranged at equal distances round it, and of such a diameter as to exactly fill up the space all round between the gudgeon and the ring. The rollers, it is evident, must be made all of one exact diameter, and extremely true, and they must fill up the space: then the gudgeon being turned round acts upon these rollers, and turns them round also at the same time by this motion. As they have no fixed centre, they also roll round within the ring *B*, in the same direction as the motion of the gudgeon, but with a very slow motion, which will be in proportion to the relative diameters of the gudgeon *C* and the ring *B*. By this means nearly all the friction is avoided, nothing like the sliding of a gudgeon round upon its bearing taking place here; it is all rolling of one surface upon another: and as the contact of two cylinders, supposing them hard, is but a line, the friction, or more properly adhesion, is exceedingly small; and at the same time that the gudgeon is as strongly supported as possible: but this depends upon the hardness of the matter of the gudgeon, the rollers, and the ring *B*. If the ring and gudgeon are made of hard cast iron, and the rollers of steel at a spring temper, it will act extremely well, though the strain or weight upon the rollers be very great. For light strains softer substances might be used, but not to so good an effect.

The manner of keeping all the rollers at their relative distances from each other, in the ring *B*, that they may not run against each other, is yet to be explained. Each roller, as shewn at *x*, has a groove turned in it in the middle of its length, so as to reduce it to a small neck in the centre: then an iron ring, *L*, is provided, which has six holes drilled in it, in the proper positions for the centres of the rollers, that is at equal distances round a circle, which is as much less than the ring *E* as the diameter of the rollers, or the same quantity larger than the diameter of the gudgeon *C*. These holes are made to fit the small neck in the centre of the rollers, and to get them in, the holes are cut open from the outside of the ring, so as to become notches; then the rollers being put into them, are all in one cluster, and in this state are introduced into the ring *E*. They will now be kept at their proper distances asunder, and when the gudgeon *C* is introduced between them, they will all take their proper places, and lie truly parallel. It is to be observed that the holes or notches in the ring *L*, do not exactly fit the necks of the rollers, which have therefore considerable play, and but very little friction, for it is not essential to keeping the rollers at their relative distances that this ring should be used, but it will prevent the danger of their getting wrong by accident. To prevent any dust or dirt getting in, which would completely destroy the action of this ingenious mechanism, a circular iron plate is fitted into the ring *B*, on each side, and both are fixed by small screws going through the ring. One of the plates *N* must of course have a hole through the middle, to admit the gudgeon. The joints of these plates should be water tight, and then a quantity of oil being poured in, will remain in the bottom of the ring *B*, and every roller, as it passes, will be kept oiled; though this is no ways necessary to their action. The end plate, which is not perforated, will make a stop to prevent the gudgeon moving endways, and the two plates will keep the rollers from shifting their position on end; but to prevent friction, if ever they come in contact, the ends of the roller should be rather convex, as shewn at *x*, that they may touch in the

centre rather than the outsidcs ; but they will never bear hard against the plate, having no drift that way.

A patent was taken out for these friction rollers many years ago, and a large manufactory was established for making them for various purposes, as carriage and waggon-wheels, the gudgeons of heavy water-wheels, &c. : they were found to possess great advantages, having scarcely any sensible friction when in motion, but were liable to get out of order chiefly from the entrance of dust, which occasioned the rollers to wear out of the round more on one side than the others ; and if once by this accident the rollers stood still for an instant, the gudgeon wore a flat place in the two rollers beneath it, and they would never run round again : a very little time would wear this flat place so deep as to stop the rollers, because of the very small surfaces in contact with the gudgeons. For delicate purposes, where hardened steel can be employed for all the rollers and the ring, they are a most admirable contrivance, and the above objections will then apply very slightly ; but, as before mentioned, their perfection and durability will ultimately depend upon the hardness of the substances employed.

Fig. 16. represents a suit of friction rollers for supporting the weight of a heavy vertical shaft, as a horse-wheel, a horizontal wind-mill, a capstan sugar-mill, &c. A A is a plate supporting the weight of the shaft ; it has a conical eminence upon it, and a hole in the centre of this, which exactly fits the pivot or gudgeon *c*, at the bottom of the shaft R : upon this gudgeon a conical plate B is formed, exactly of the same shape and size as the conical part of the plate A, and between these two plates three or four rollers *a, a*, are situated, and bear the weight of the shaft R, or whatever presses upon the plate B. The rollers are kept at proper distances asunder by a ring, shewn separate at L, with three arms, *n*, projecting from it, which being formed into spindles, pass through the centres of the rollers *a*, and have collets and cross keys to keep them on. In this manner, as the gudgeon and plate B turn round, the plate rolls upon the rollers *a, a*, keeping always in the true centre, by the end of the gudgeon *c* fitting the hole in the centre of the plate A A ; but the weight is supported by the rollers *a, a*, which, at the same time that the upper plate rolls upon them, they roll upon the lower, and thus very considerably diminish the friction which any other kind of gudgeon would have in such a situation.

Shafts.—In almost all modern mills, the shafts or spindles for the conveyance of motion, and support of wheels, are made of iron, either wrought or cast. Square shafts are the most common, but sometimes octagon and round ones are used ; and if they are very large, they are cast hollow, like pipes, and the gudgeons fixed in at the ends by wedges ; but the pivots should always, if possible, be formed of the same piece of metal, as the slightest possible deviation from the straight line causes them to strain, and work very irregularly in their bearings. In wooden shafts this is impracticable, and it is one of the greatest objections to the use of them. The best method of fixing gudgeons into wooden shafts is shewn in *fig. 17*. Here A is the gudgeon, made in cast iron, turned true ; it has four leaves, *a, b, c, d*, forming a cross, which is let into the end of the wooden shaft R : the front edge of each leaf is considerably thinner than the back, so that a pair of strong iron hoops *r r* being driven tight on the end of the shaft, closes the wood round the cross, and holds it fast, and the back of the leaves being wider than the front, it will not come out. As an additional security, screws are sometimes put in : these are put through holes in the arms of the cross, which are then made flat the other way, and do not go so far into the wood. The screws go into the timber a considerable distance, where a mortise is cut into the wood, to meet

the end of the bolt, and an iron nut is dropped in, to screw the bolt into, when it is turned round by a screw driver. By this contrivance a gudgeon may be fitted into a wooden shaft very fast, but still it will never come into competition with iron shafts, when the gudgeon is made all in one solid piece with the whole of the shaft. A judicious mechanic will never make more than two bearings upon any one shaft, if it can be avoided, because if the three, by any means, as the warping of the frame work, or other cause, get the smallest possible quantity out of the straight line, they can never work well afterwards, but will always strain and wear the bearings with great friction. In very extensive mills, such as woollen and cotton mills, breweries, &c. when the buildings are of great length, it becomes necessary to join several shafts together in length, to reach from one end to the other of a mill. The manner of making the joinings is of some consequence : it is necessary that every shaft should have a bearing at each end, and consequently that the connection of the ends of every one should be made by uniting the ends of the shafts which project beyond their bearings. This can be done in various ways : one is by having the ends of each of the shafts provided with circular heads (see A B *fig. 18.*), which have teeth in one, and corresponding indentations in the other, to receive them, and thus one is made to turn the other about, at the same time that if any slight settlement of the building or other cause depresses one of the bearings, or raises another, so as to put the two shafts out of the perfect straight line they ought always to preserve ; these joints will admit the slight flexure, and still communicate the motion of one shaft to the other.

As this accidental settlement in large buildings is almost unavoidable in some degree, care should be taken to make such joints as will admit of a trifling bending. Sometimes the ends of the shaft are made circular, and turned quite true in the lathe ; then a metal tube or collar is fitted truly upon both to cover the joint, and connect them, a bolt being put through each end, which unites both shafts with the collar, and thus by means of it causes one to turn the other round. This method is sometimes used to save the great expence of having a bearing at each end of every length of shaft, one bearing to each length being then sufficient, the other end of the shaft being supported by this collar, connecting it with the end of the adjacent length just where it projects beyond its bearing. But this is not a good method, as the shafts are apt to bend and work with so much friction in the bearings, if they get the least out of the straight line, because these kind of joints will not admit any flexure of the shaft, or if they do, they will only bend on one side, whereas it is necessary for the joint to bend successively on all sides, when the bearings are not precisely in a straight line. *Plate III. fig. 19.* represents a coupling-box, used by Mr. Murray of Leeds, for connecting the lengths of a long line of shaft which are to carry a heavy strain : it is so made that it will communicate the motion in the manner of an universal joint, if they should be out of the line. Let A, B, be the two shafts to be united ; C, D, their necks or collars which lay in the bearings : the ends projecting beyond these have boxes E, F, fixed on them, either by a square with wedges, or by a round part with a fillet : one of these boxes, E, has a piece projecting from the inside of it on each side, and extending into the other box, as is shewn at *a a*, (No. 2.), which is an inside view : the other box, F, has two similar pieces projecting from it at *b b* into the other box E : within the boxes an iron cross *c c d d* is situated ; it has screws fixed into the ends of the cross, and by these the motion is communicated : thus, the pieces *a, a*, when the shaft A and box E are turned round in the direction of the arrow (No. 2.) act against the screws *c, c*, of the cross, and turn

It about : at the same time the other two screws *d, d*, at the other arms of the cross press against the pieces *b, b*, which belong to the box F and shaft B, thus turning them round : the cross is placed quite detached in the boxes, and thus acts as an universal joint, to communicate the motion of one to the other : the screws *c, c, d, d*, at the ends of the crosses are only put in that the acting points may be made of steel, and made smooth to have but little friction in these parts. Another method of uniting shafts by Mr. Murray is shewn at *fig. 20* : it has the advantage of requiring only one bearing for every length of shaft, whereas the above method requires one for each end of every length. A, B, represent the two shafts ; each has a pivot formed at the end : these pivots are fitted into a coupling piece C D E, which is bored out truly to fit them inside, and the outside turned true, with a neck D D, which is received and fitted into a bearing : the two shafts A, B, are connected with the coupling piece D, at C and E, by means of a cross key *lm*, put through each shaft, and the ends of them received in notches made within of the coupling piece at C and E, where it receives the ends of the shafts. It is to be observed that the shafts do not fit tight in these parts E and C, but only in the pivots *a, b*, within, by which means they have liberty of a little motion, and this without straining the bearing in which D runs, because it is only the short coupling piece which is received therein ; and consequently, any trifling deviation from the straight line will not strain it, because of the play allowed in the fittings.

The universal joint, called also Hooke's joint, from its inventor Dr. Hooke, is a method of uniting shafts, which permits them to be rather inclined to each other. This is shewn in *fig. 21*, where A, B, are the two shafts, with necks to be received in bearings : each shaft beyond this is formed into a fork, as C and D ; and these are united by a cross of iron E, or sometimes a ring, in which four pins are inserted, and pass through holes in the ends of the forks. On one or other of these pins the joint will bend in any direction, on the same principle as a compass hangs in its gimbals, and will communicate a rotative motion from one shaft to the other, when they are rather inclined ; but this inclination should be small, or else the joint will not act well, or without great friction, and irregularity of motion. If an angle of more than 15 degrees from the straight line is required, a pair of slightly bevelled wheels are best.

The regulation of the velocity of a mill is a matter of considerable importance, to preserve an uniformity of motion, either when the force of the first mover is fluctuating, or when the resistance or work of the mill varies in its degree : either or both of these causes will occasion the mill to accelerate or diminish its velocity ; and in many instances it will have a very injurious effect upon the operations of the mill. Thus, in a mill for spinning cotton, wool, flax, &c. driven by a water-wheel, are a multiplicity of movements, many of which are occasionally disengaged, in different parts of the mill, for various purposes. This tends to diminish the resistance to the first mover, and the whole mill accelerates. Or, on the other hand, the head of water, which drives the wheel, may be liable to rise and fall suddenly, from many causes, which great and rapid rivers are subject to, and cause similar irregularities in the speed of the wheel. For such cases, judicious mechanics have adopted contrivances, or regulators, which counteract all these causes of irregularity ; and a large mill, so regulated, will move like a clock, with regard to its regularity of velocity. These regulators are usually termed *governors*, and are made on different principles. Those most generally used are called flying-balls, operating by the centrifugal force of two heavy balls, which are connected and revolve with a vertical axis. *Fig. 22.* re-

presents the simplest form of this ingenious apparatus : A A is the vertical axis, which is constantly revolving by the machinery ; at *aa* two arms or pendulums, *ab, ab*, are jointed, and carry at their extremities a heavy metal ball each, as *bb* ; from the pendulums two chains or iron rods, *d, d*, proceed, and suspend a collar *e*, which slides freely up and down the axis, and has a groove formed all round it, in which the end of a forked lever, D, is received ; and thus the rising and falling of the collar, *e*, produces a corresponding motion of the end of the lever D ; but the collar is always at liberty to turn round with the axis freely within the fork, at the extremity of the lever. The operation of the governor is this : when the vertical axis is put in motion, the centrifugal force of the balls, *b, b*, causes them to recede from the centre ; and as this is done both together, they cause the collar, *e*, and the end of the lever to rise up : the balls fly out to a certain height, and there they continue as long as the axis preserves the same velocity ; as it is the property of a pendulous ball, like *b*, to make a greater effort to return to the perpendicular, in proportion as it is removed farther from it, in consequence of the suspending rod being more inclined, and bearing less of its weight. The weight of the balls to return to the axis may be considered as a constantly increasing quantity ; while the quantity of the centrifugal force, causing them to recede from the axis, depends exactly upon the velocity given them. But this velocity increases as they open out, (independently of any increased velocity of the axis,) in consequence of their describing a larger circle. The combination of these oppositely acting forces causes the governor to be a most sensible and delicate regulator. Thus : suppose the balls hanging perpendicular, put the axis in motion with a certain velocity, the centrifugal force will cause the balls to fly out ; and this increasing their velocity, (by putting them farther from the centre, and causing them to revolve in a larger circle,) gives them a greater centrifugal force, which would carry them still farther from the centre, but for the counteracting force, *viz.* the weight of the balls tending to return. This is, as before stated, an increasing quantity, and consequently these opposite forces come to a point where they balance each other ; that is, the balls fly out till their weight to return balances the centrifugal force. But if the slightest alteration takes place in the velocity of the axis, the equilibrium is destroyed by the increase or diminution of the centrifugal force, and the balls alter their distance from the centre accordingly, and by elevating or depressing the end of the lever, operates upon some part of the mill to rectify the cause of the irregularity. In a steam-engine, the lever acts upon a vane or door situated in the passage of the steam from the boiler to the cylinder ; and if the mill loses in velocity, from an increase of resistance, the balls fall together a little ; and the consequent fall of the lever opens the door or throttle valve a little wider, and gives a stronger supply of steam to restore the mill to its original velocity. On the other hand, if the mill accelerates, the balls open out and then close the vane, so as to moderate the supply of steam. See a more full description of this under *STEAM-Engine*.

A water-wheel is not so easily regulated by the governor, because the shuttle of a large wheel requires a much greater force to raise or lower it, when the water is pressing against it, than the lever, D, can at any time possess ; it therefore becomes requisite to introduce some additional machinery, which has sufficient power to move the shuttle, and this is thrown, in or out of action, by the flying balls. The simplest contrivance, and that which we believe was the regulator first used for a water-wheel, was erected at a cotton mill at Belper, in Derbyshire, belonging to Mr. Strutt.

A square well, or large cistern, was situated close by the water-wheel: it had a pipe leading from the mill-dam into it, to admit water; and another pipe from it to the mill-tail, to take the water away: both were closed at pleasure by cocks or sluices. Within the well was a large floating chest, very nearly filling up the space: it of course rose and fell with the water in the cistern, and had a communication by rack and wheel-work with the machinery for drawing the shuttle, so that the rise and fall of the floating chest elevated and depressed the shuttle of the wheel. The lever of the governor was connected with the cocks in the two pipes, in such a manner that when the mill was going at its intended velocity, both of the cocks were shut; but if the water-wheel went too slowly, the falling of the balls and descent of their lever, D, opened the cock in the pipe of supply, and, by letting water into the well, raised the float, and, with it, the shuttle, to let more water upon the wheel, till it acquired such a velocity that the balls began to open out again, and thus shut the cock: on the other hand, if the mill went too fast, the balls opened the pipe of exit from the well, and then the sinking of the float closed the shuttle till the true velocity was restored.

Since this first application of the regulator to the water-wheel, the manner of its operation has been greatly varied; and as the same mechanism is applicable to any kind of mill-work, we shall give a slight sketch of it. Suppose A, *fig. 23*, an axis, receiving its motion from the mill by wheel-work; it is provided with a pair of governors, *a b, a b*, constructed like those before described; and at the lower part of the spindle is a bevelled wheel, R, turning two others, B and C, situated upon one spindle, D, which goes away, and communicates motion to the racks of the shuttle; the wheels, B and C, are neither of them fixed to the spindle D, but both slip round freely upon it, turning in contrary directions, as they receive motion from the opposite sides of the wheel R. A locking clutch, *d*, is fitted upon the spindle between these two wheels, B, C, and can, by moving it one way or the other, be made to lock either one of the wheels to the spindle D, at the same time that it leaves the other disengaged. The locking-box is moved by means of a lever, shewn in *fig. 24*; the arm *m*, having a fork to embrace a groove in the box; the lever is fixed on a vertical axis *n*, which has at the upper end two other levers, *o, p*: these lay one on each side of the vertical axis A, but at different heights, as is evident from the figure. The collar *e*, which is raised up when the balls fly out, is fitted upon a square part of the spindle A, and is formed like a snail or cam, which will act upon either of the levers, *o* or *p*, according to the height at which it hangs upon its spindle. Now when the mill is going with its true velocity, this cam, *e*, is at such a height that it is beneath one lever, *o*, and above the other, *p*, so as to interfere with neither; consequently the locking-box, *d*, remains detached: but on any alteration in the velocity of the mill and the axis A, the balls open or shut, as before explained, and the cam, *e*, either rises or falls, and then it presses against one of the levers, *o* or *p*, and by pushing it away from the axis, it moves the lever *m*, and the locking-box *d*, up to one of the wheels, B or C, which it locks to the axis D, and turns it round in the direction of that wheel's motion, by which it either raises or depresses the water-wheel's shuttle, as is required. This apparatus may, it is plain, be applied to any other kind of mill-work.

Governors or flying-balls are very frequently used in the wind-mills employed for grinding flour: the variable force of this first mover renders some such regulator necessary, to increase the resistance, by allowing a greater feed of corn,

when the mill moves too quickly, and thus in some degree counteracting the irregularity. If the mill moves too slowly, the balls tend to diminish the feed, and at the same time they raise the upper stone, to set them at a greater distance asunder, that they may require less power to drive them, and consequently suffer the mill, as nearly as it can, to retain its full velocity, though the motive force is greatly diminished. This application of the governor was, we believe, first made by the ingenious captain Hooper of Margate, who invented the horizontal wind-mill. (See *WIND-MILL*.) It is a very great advantage, and no wind-mill should be without them. Many wind-mills are provided with flying-balls, which, by very ingenious mechanism, clothe and unclothe the sails just in proportion to the strength of the wind.

In many mills it is of consequence to be able to detect small variations in the velocity, and to ascertain the quantity of them; for the governor only corrects the irregularities, without shewing any scale of them. In cases where this is required, it may be done by a very ingenious instrument, invented by Mr. Bryan Donkin of Fort-Place, Bermondsey. He received a gold medal from the Society of Arts, Manufactures, and Commerce, in 1810, for this instrument, which he calls a tachometer.

A front view of this instrument is represented in *fig. 25*, and a side view in *fig. 26*, of *Plate II*. XYZ, *fig. 25*, is the vertical section of a wooden cup, made of box, which is drawn in elevation at X, *fig. 26*. The whiter parts of the section, in *fig. 25*, represent what is solid, and the dark parts what is hollow. This cup is filled with mercury up to the level LL, *fig. 25*. Into the mercury is immersed the lower part of the upright glass tube AB, which is filled with coloured spirits of wine, and open at both ends, so that some of the mercury in the cup enters at the lower orifice, and, when every thing is at rest, supports a long column of spirits, as represented in the figure. The bottom of the cup is fastened by a screw to a short vertical spindle D, so that when the spindle is whirled round, the cup (whose figure is a solid of revolution) revolves at the same time round its axis, which coincides with that of the spindle.

In consequence of this rotation, the mercury in the cup acquires a centrifugal force, by which its particles are thrown outwards, and that with greater intensity, according as they are more distant from the axis, and according as the angular velocity is greater. Hence, on account of its fluidity, the mercury rises higher and higher as it recedes from the axis, and consequently sinks in the middle of the cup; this elevation of the sides and depression in the middle increasing always with the velocity of rotation. Now the mercury in the tube, though it does not revolve with the cup, cannot continue higher than the mercury immediately surrounding it, nor indeed so high, on account of the superincumbent column of spirits. Thus the mercury in the tube will sink, and consequently the spirits also; but as that part of the tube which is within the cup is much wider than the part above it, the depression of the spirits will be much greater than that of the mercury, being in the same proportion in which the square of the larger diameter exceeds the square of the smaller.

Let us now suppose, by means of a cord passing round a small pulley F, and the wheel G or H, or in any other convenient way, the spindle, D, is connected with the machine whose velocity is to be ascertained. In forming this connection, we must be careful to arrange matters, so that when the machine is moving at its quickest rate, the angular velocity of the cup shall not be so great as to depress the spirits below,

C, into the wider part of the tube. We are also, as in the figure, to have a scale of inches and tenths applied to A C, the upper and narrower part of the tube, the numeration being carried downwards from zero, which is to be placed at the point to which the column of spirit rises when the cup is at rest.

Then the instrument will be adjusted, if we mark on the scale the point to which the column of spirits is depressed when the machine is moving with the velocity required. But, as in many cases, and particularly in steam-engines, there is a continued oscillation of velocity; in those cases we have to note the two points between which the column oscillates during the most advantageous movement of the machine.

Here it is proper to observe, that the height of the column of spirits will vary with the temperature, when other circumstances are the same. On this account the scale ought to be moveable, so that, by slipping it upwards or downwards, the zero may be placed at the point which the column reaches when the cup is at rest, and thus the instrument may be adjusted to the particular temperature with the utmost facility, and with sufficient precision. The essential parts of the tachometer have now been mentioned, as well as the method of adjustment; but certain circumstances remain to be stated.

The form of the cup is adapted to render a smaller quantity of mercury sufficient than what must have been employed either with a cylindrical or hemispherical vessel. In every case two precautions are necessary to be observed. First, that when the cup is revolving with its greatest velocity, the mercury in the middle shall not sink so low as to allow any of the spirits in the tube to escape from the lower orifice; and that the mercury, when most distant from the axis, should not be thrown out of the cup. Secondly, that when the cup is at rest, the mercury shall rise so high above the lower end of the tube that it may support a column of spirits of the proper length.

Now, in order that the quantity of mercury, consistent with these conditions, may be reduced to its minimum, it is necessary, first, that if M M (*fig. 1.*) is the level of the mercury at the axis when the cup is revolving with the greatest velocity, the upper part M M X Y of the cup should be of such a form as to have the sides covered only with a thin film of the fluid; and secondly, that, for the purpose of raising the small quantity of mercury to the level L L, which may support a proper height of spirits when the cup is at rest, the cavity of the cup should be, in a great measure, occupied by the block K K, having a cylindrical perforation in the middle of it for the immersion of the tube, and leaving sufficient room within and around it for the mercury to move freely, both along the sides of the tube and of the vessel.

The block, K K, is preserved in its proper position in the cup or vessel X Y Z, by means of three narrow projecting slips or ribs, placed at equal distances around it, and is kept from rising or floating on the mercury by two or three small iron or steel pins inserted into the underside of the cover, near the aperture through which the tube passes. It would be extremely difficult, nor is it by any means important, to give to the cup the exact form which would reduce the quantity of mercury to its minimum; but we shall have a sufficient approximation, which may be executed with great precision, if the part of the cup above, M M, is made a parabolic conoid, the vertex of the generating parabola being at that point of the axis to which the mercury sinks at its lowest depression, and the dimensions of the parabola will be determined in the following manner. Let V G (*fig. 27.*) represent the axis of the cup, and V the point to which the mer-

cury sinks at its lowest depression: at any point, G, above V, draw G H perpendicular to V G; let n be the number of revolutions which the cup is to perform in 1", at its quickest motion; let v be the number of inches which a body would describe uniformly in 1", with the velocity acquired in falling from rest through a height = to G V,

and make G H = $\frac{314 n}{v}$. Then the parabola to be deter-

mined is that which has v for its vertex, V G for its axis, and G H for its ordinate: at G the cup has a lid to prevent the mercury from being thrown out of it, an event which would take place with a very moderate velocity of rotation, unless the sides were raised to an inconvenient height; but the lid, by obstructing the elevation of the sides of the cup, will diminish the depression in the middle, and, consequently, the depression of spirits in the tube: on this account, a cavity is formed in the block immediately above the level L L, where the mercury stands when the cup is at rest, and thus a receptacle is given to the fluid which would otherwise disturb the centrifugal force, and impair the sensibility of the instrument.

It will be observed, that the lower orifice of the tube is twined upwards. By these means, after the tube has been filled with spirits, by suction, and its upper orifice stopped with the finger, it may easily be conveyed to the cup, and immersed in the quicksilver, without any danger of the spirits escaping, a circumstance which otherwise it would be extremely difficult to prevent, since no part of the tube can be made capillary, consistently with that free passage to the fluids which is essentially necessary to the operation of the instrument.

We have next to attend to the method of putting the tachometer in motion, whenever we wish to examine the velocity of the machine. The pulley F, which is constantly whirling during the motion of the machine, has no connection whatever with the cup, so long as the lever, Q R, is left to itself. But when this lever is raised, the hollow cone T, which is attached to the pulley, and whirls along with it, is also raised, and, embracing a solid cone on the spindle of the cup, communicates the rotation by friction. When our observation is made, we have only to allow the lever to drop by its own weight, and the two cones will be disengaged, and the cup remain at rest.

The lever, Q R, is connected, by a vertical rod, to another lever S, having at the extremity, S, a valve, which, when the lever, Q R, is raised, and the tachometer is in motion, is lifted up from the top of the tube, so as to admit the external air upon the depression of the spirits. On the other hand, when the lever, Q R, falls, and the cup is at rest, the valve at S closes the tube, and prevents the spirits from being wasted by evaporation.

It is, lastly, to be remarked, that both the sensibility and the range of the instrument may be infinitely increased; for, on the one hand, by enlarging the proportion between the diameters of the wide and narrow parts of the tube, we enlarge, in a much higher proportion, the extent of scale corresponding to any given variation of velocity; and, on the other hand, by deepening the cup, so as to admit, when it is at rest, a greater height of mercury above the lower end of the tube, we lengthen the column of spirits which the mercury can support, and, consequently, enlarge the velocity which, with any given sensibility of the instrument, is requisite to depress the spirits to the bottom of the scale. Hence the tachometer is capable of being employed in very delicate philosophical experiments, more especially as a scale might be applied to it indicating equal increments of

velocity. But, in the present account, it is merely intended to state how it may be adapted to detect, in machinery, every deviation from the most advantageous movement.

Fig 1.

Fig 1

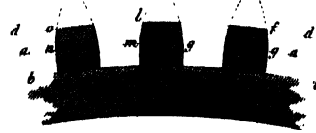
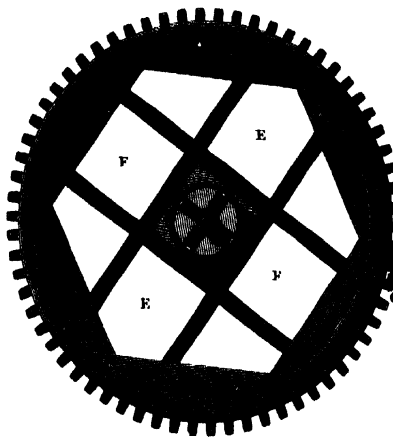


Fig 2.

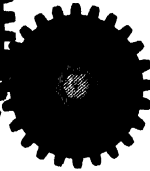
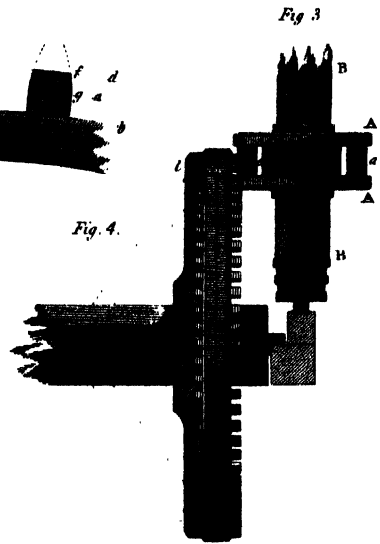


Fig. 4.



Bevilled Wheels.

Fig 5

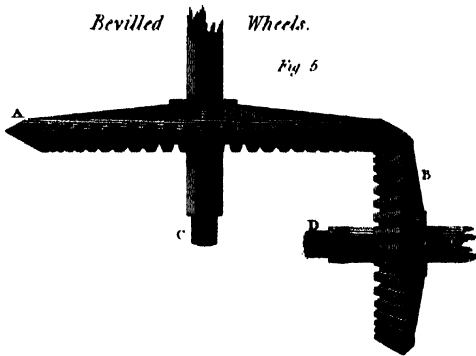


Fig 6

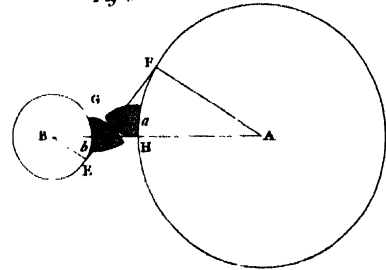


Fig 8

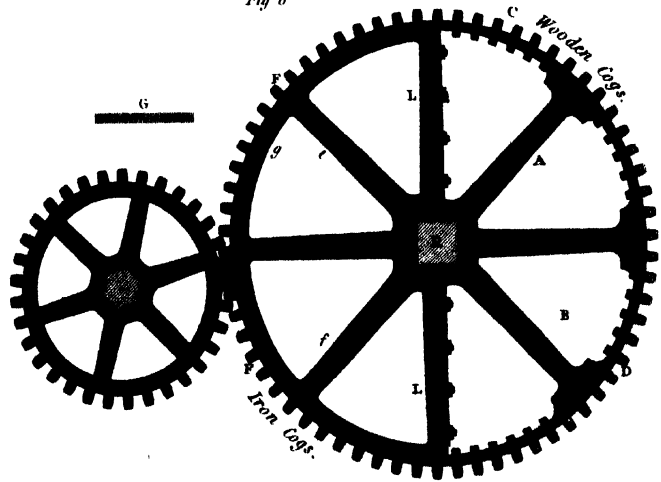
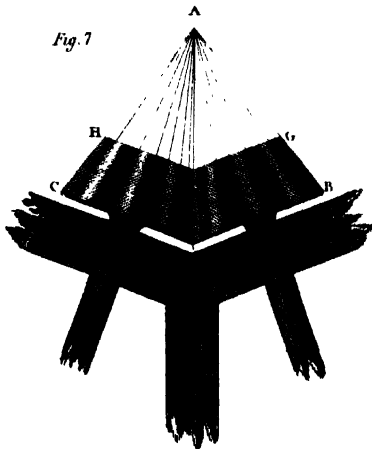


Fig. 7



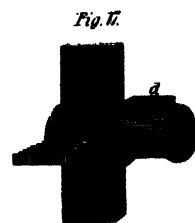
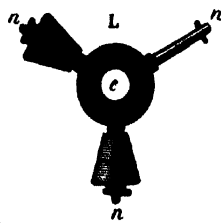
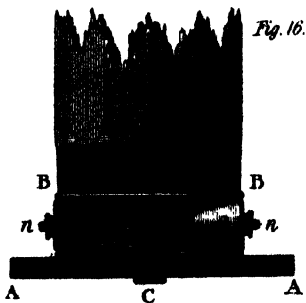
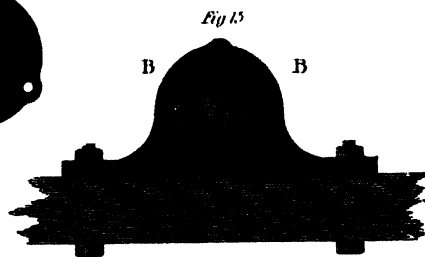
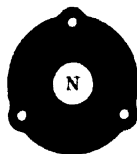
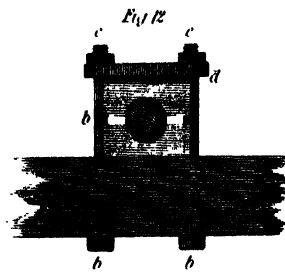
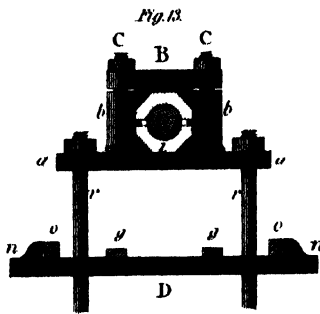
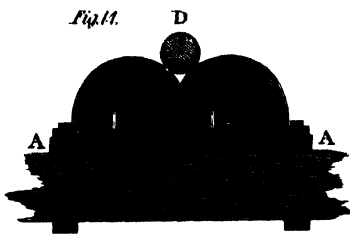
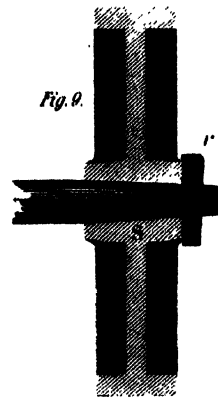
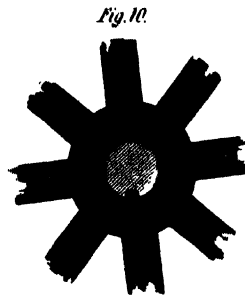
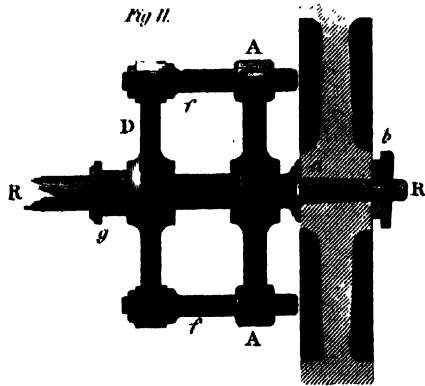
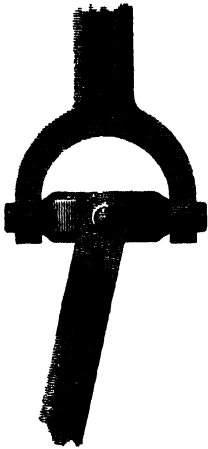


Fig. 21.



N^o 1.

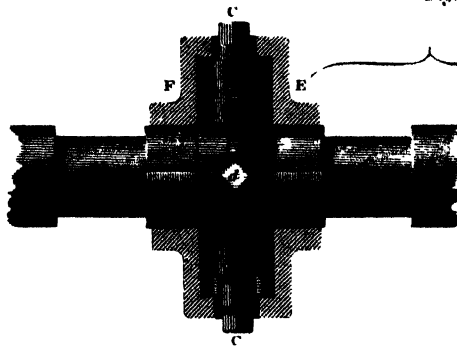


Fig. 19.

N^o 2.

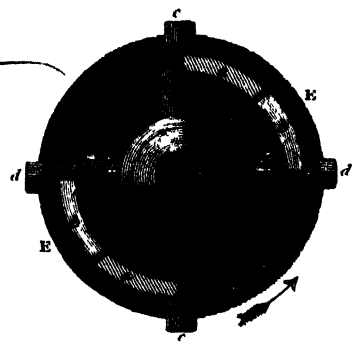


Fig. 18.



Fig. 20.

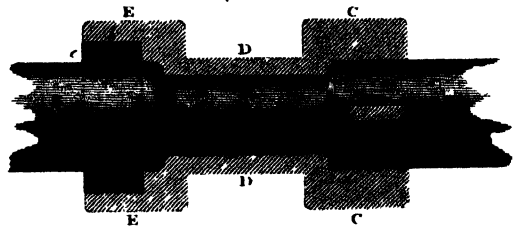


Fig. 22.

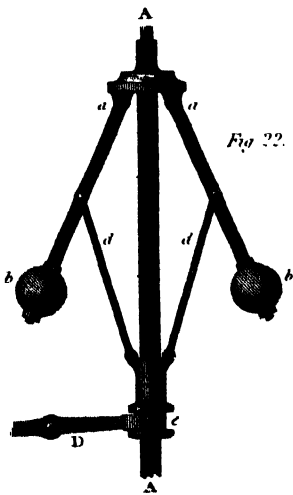


Fig. 23.

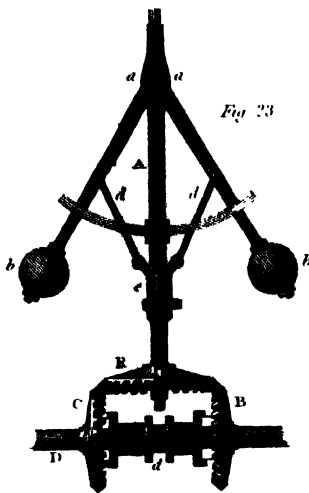


Fig. 26.

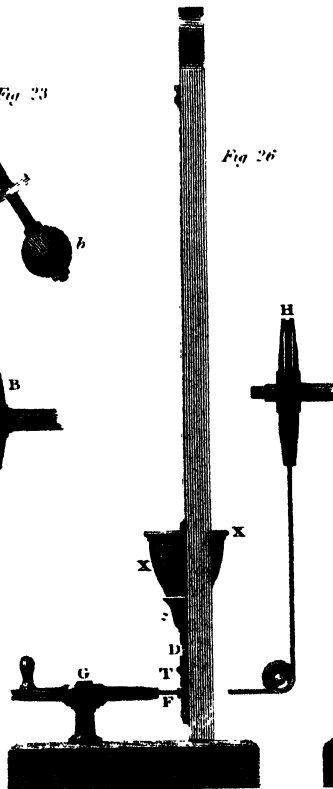


Fig. 25.

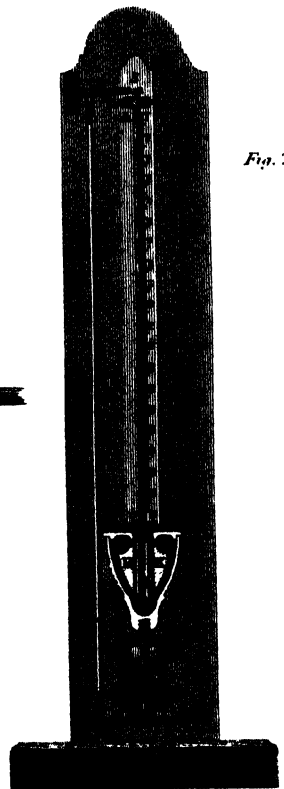
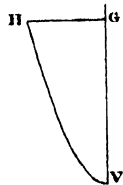


Fig. 24.



Fig. 27.



Milling

MILLING, in the *Manufactories*, an operation called also *fulling*.

MILLING, or *throwing of silk*, is the last preparation of silk before dyeing ; serving to twist it, more or less, according to the work for which it is intended.

To prepare the silk for milling, they first put it in boiling water, inclosed between two linen cloths. The mill is a square machine, composed of several pieces of wood, mortised in each other, so as to form a kind of large cage, in the centre of which are two wheels placed parallel over each other, whose axis bears on two posts. When the machine is simple, a single man turns these wheels by means of a little cog, in which they catch, and a large handle.

The wheels, put in motion by the handle, communicate

their motion to eight windles, or reels, or even more, according to the largeness of the machine ; on the flights or arms of which the silk is wound from off two rows of bobbins placed on each side of the machine ; each row at the height of one of the two wheels in the centre. These bobbins have their motion by means of leathern thongs, which bear on little cylinders of wood that support them, and turn at length on the two wheels at the centre ; so that the silk on each bobbin twists as it winds, and forms its separate skain.

The smallest wheel moves two hundred of these bobbins, over which a single person is sufficient to inspect, to put new bobbins or spoils in lieu of those discharged of their silk, and to knot the ends when they break. See *WINDING of Silk*.

Mine

MINE. This word is applied generally to all works carried on under ground, but seems principally to belong to such as have for their object the discovery and production of the metallic ores.

The construction of the works in various mines differs according to circumstances, such as the form of the hills in which they are situated, or the position of the ores, whether found in veins or beds. Some mines are formed by a level or drift entering the foot of a mountain, and extending to the deposits of metal within it, which may be taken away and carried out through this opening; and in this case *shafts* are only required for the purposes of ventilation.

This seems to be the simplest state of mining, and is, as well as such mines as have been formed by following ore from the surface to such depths as water would permit, to be ranked among the earlier efforts of this kind.

The more extended operations of mining are to be found where regular metallic veins, situated in primitive rocks, are worked to great depths below the level of the sea, where perpendicular *shafts*, drained of the constantly accumulating water by engines, form the means of communication from the surface to *levels* driven upon the *lode* or vein, at various and successive depths, so as to open all parts of it for the discovery of its contents.

A mine thus constructed, of any considerable extent, is one of the most extraordinary instances of human enterprise, patience, and ingenuity; especially if it be considered that its formation depends upon the application of two of the most wonderful discoveries on record, the expansive forces of gunpowder and steam.

Mines in Cornwall and Devon are generally worked by a company of proprietors, called adventurers, who agree with the owner of the land, or lord of the soil, as he is usually denominated, to work the mine for a certain term of years, paying him, by way of rent, a proportion of the ores raised, or an equivalent in money. The grant thus made to the adventurers is called a *fee*, and the lord's rent, if paid in ore, is called the *disb* (probably from the ancient practice of measuring it by a vessel of that sort), and when settled for in money, has the term *dues* applied to it.

The adventurers divide their undertaking into shares of different magnitude, but usually forming in the whole some even and easily divisible number. The smallest share usually held by one adventurer is one sixty-fourth part, though in some large mines this share is divided, and a person may then have only a one hundred and twenty-eighth part of the whole, while others may hold eighths, others sixteenths or thirty-seconds, and some larger proportions, but the whole added together make up sixty-four shares. Any part of the concern held by one person is generally called a *dole*, and distinguished as to its relation to the whole by adjoining to this word the denomination of its value, as an eighth dole, a sixteenth dole, &c.

Mines in Cornwall and Devon are usually named as soon as they are undertaken, and this practice seems to have been of considerable antiquity, as the word *wheal*, or *huel*, usually even now prefixed to these appellations, is derived from the ancient Cornish language, and signifies a work or mine. The other parts of the names of mines often relate to the situation, or have been given in compliment to some person connected with them, or adopted according to the fancy of the adventurers. Thus Wheal Rose is probably derived from the

Cornish word *ros*, a valley, and means therefore the mine in the valley; Wheal Godolphin has the name of a family; and among the arbitrary appellations which are the most numerous, may be instanced Wheal Unity, Wheal Virgin, Wheal Jewel, &c.

The *bounds*, or limits of the set of a mine, are usually marked out upon the surface and include the space of ground in which any company of adventurers have contracted for the right working. Bounds for working tin are recognized by the stannary laws of Devon and Cornwall, as a property in themselves distinct from the possession of the soil, and were probably originally granted to encourage the search for this metal by the laws of the duchy, that the revenue of the chief lord might not suffer by the unwillingness of the possessor of the soil to have its surface disturbed. Tin bounds that have been legally renewed, or possession retained, are even now in their original state in this respect; but copper mines, and also many tin mines, are now generally held of the possessor of the fee.

Mines are generally conducted in Cornwall and Devon by a manager appointed by the adventurers, who hold meetings at the counting-house to revise and pass the accounts, and to debate and determine on all subjects relative to the prosecution of the works submitted to them.

Under the principal agent others are appointed, who are practical miners, and who superintend the various operations and settle the terms of the contracts with the workmen, which are made by a kind of public auction. These agents are called *captains*, and the number employed in a mine is in proportion to its extent and importance. Some attend principally to the works below, and are therefore called *under-ground captains*; others take charge of the operations on the surface, and are therefore distinguished by the appellation of *grist captains*. It would be injustice to this useful and respectable body of men to pass them over without noticing the intelligence, activity, and skill by which the agents of the mines in the districts alluded to are distinguished.

The establishment of a mine further includes occasionally an engineer, a head carpenter and smith, who have each their workmen under their care; a *pitman*, who directs the fixing and repair of the pump-work; a *timberman* or *binder*, who superintends the construction of the woodwork under ground, for securing the shafts, ladders, levels, and so on; and besides these operative men, there are usually clerks to keep the accounts, and persons to receive and deliver to the workmen the materials used in their operations.

The miners working under ground are divided into two classes, according to the mode by which they are paid. Those of the first class are called *tributers*, who work on the productive parts of the mine, and receive a proportion of the ore which they procure and make merchantable, for their labour. This mode of payment, by its occasionally leading to unusual profit, stimulates to great exertion in the discovery of fresh deposits of ore, and is therefore conducive to the interests of the employer as well as the workman. To the reward thus held out to skill and intelligence, may probably be attributed the prevalence of these qualities, which may be observed more particularly in this class of Cornish miners. The other workmen employed under ground are denominated *tutwork-men*, who agree for sinking shafts, driving levels, and so on, at a certain price *per fathom*. These prices are exceedingly various, as the rock to be penetrated differs in de-

gress of hardness, or the nature of the work exposes the men to more or less danger or inconvenience from water or bad air.

The people employed on the surface in dressing the ores, generally perform their labour by task-work, the amounts being charged to the account of the tributers, whose ore is undergoing this process.

The copper ores, when ready for sale, are sampled by agents of the smelting companies, who visit the mines for that purpose, and are sold on a fixed day by a public sale, called a *ticketing*, and afterwards weighed and carried to a port and shipped to Wales, where the copper smelting houses in general are. Tin ores are smelted in Cornwall, and are sold by the miner to the owners of the smelting houses by private contract, valuing them by an assay made by the buyer. In this respect the value of tin ores is determined by a mode much more uncertain and irregular than that employed for copper, the assay of which is conducted with extreme care, and wonderful accuracy.

The extent of the returns and costs of the mines in Cornwall and Devon, both collectively and separately, may be seen by referring to the history of mining in this district, where the tables of the state of these concerns exhibit a very interesting picture of the great increase of these extensive undertakings. See *MINING, History of*.

The king by his prerogative hath all mines of gold and silver to make money; and therefore those mines, which are properly royal, and to which the king is entitled when found, are only those of silver and gold. (2 Inst. 577.) By the old common law, if gold or silver be found in mines of base metal, according to the opinion of some, the whole was a royal mine, and belonged to the king; though others say that this was only the case, when the quantity of gold or silver was of greater value than the quantity of base metal. (Plowd. 336.) But by statute no mines of copper, tin, iron, or lead, shall be adjudged royal mines, though gold or silver be extracted. (1 W. and M. c. 30.) And persons having mines of copper, tin, lead, &c. shall enjoy the same, although claimed to be royal mines; but the king, or persons claiming royal mines under his authority, may have the ore (except tin-ore in Devon and Cornwall) paying to the owners of the mines, within thirty days after it shall be raised, and before removed, 16*l.* per ton for copper-ore washed, and made merchantable; for lead-ore 9*l.* per ton; tin or iron, 40*s.* &c. (Stat. 5 W. & M. c. 6.) If any person maliciously set on fire any mine, or pit of coal, he shall be guilty of felony,

without benefit of clergy, by stat. 10 Geo. II. c. 32. If any person shall wilfully or maliciously set fire to, burn, demolish, pull down, or otherwise destroy or damage any fire-engine, or other engine erected for draining water from coal mines, or for drawing coals out of the same; or for draining water from any mine of lead, tin, copper, or other mineral, or any bridge, waggon-way, or trunk erected for conveying coals from any coal mine, or staith for depositing the same; or any bridge, or waggon-way erected for conveying lead, tin, copper, or any other mineral, from such mine, or cause the same to be done, he shall be guilty of felony, and transported for seven years. (9 Geo. III. c. 29.) Provided that no person be prosecuted under this act beyond 18 months after the offence committed. By 39 & 40 Geo. III. c. 77, destroying or damaging mines or roads leading to or from the same, &c. incurs the guilt of misdemeanor, and any one person so offending may, on conviction, be imprisoned for any time not exceeding six months. Colliers and miners working in a manner contrary to their agreement, or not fulfilling their contracts, shall, on conviction, forfeit not exceeding 40*s.* and on non-payment be imprisoned for a time not exceeding six months, or until the penalty and costs shall be paid. Stealing ore out of mines is no larceny, except only those of black-lead, the stealing ore out of which is felony, punishable with imprisonment and whipping, or transportation not exceeding seven years, and escaping from such imprisonment, or returning from transportation is felony, without benefit of clergy, by 25 Geo. II. c. 10.

MINE-adventurers, Company of, had its first rise about the year 1690, when certain mines of lead and copper were found in South Wales, which were divided by the proprietors into twenty-four shares; and in 1693 sub-divided into four thousand and eight shares, for the term of twenty-two years and a half; to which term five years more were added in 1698, and the affairs of the company regulated by a new constitution. In 1704, queen Anne granted a charter of incorporation to this company; in consequence of which several new shares were added, so that the whole number amounted to six thousand and twelve. However, the interests of this corporation were so ill managed, that the proprietors and creditors petitioned parliament in 1710, and a committee of the house of commons was appointed to enquire into its state. The result of the enquiry was a censure on the principal managers; and though, in 1711, a law was passed for the better regulation of the company, and the relief of the creditors and proprietors, nothing could preserve it from sinking.

Mining

MINING, *History of.* To trace this subject up to its earliest stages, and to exhibit the various combinations of human ingenuity which it has in successive periods produced, though an inquiry which might afford matter for curious speculation, would be one which, if we were to take into the view the progress of mining in all the different countries where metals have been found, would extend the subject to a length hardly admissible in any work not wholly devoted to this object.

From the simplest operations, mankind have been gradually led, by following the pursuit of the metals, to efforts the most complex and astonishing. At first it may be assumed, not only from the probability of the thing, but from evidence which even this country affords, in the remains of ancient works of this kind, that metals were procured from detached fragments of the ores, such as had been separated by various causes from the upper parts of the veins in which they were originally deposited: and in this manner is gold yet procured, by washing the sands of certain rivers; and tin even now sought after, under beds of gravel, in the vallies of Cornwall and Devon.

The pursuit of scattered pieces of ore naturally would conduct the persons, who were thus employed, to the beds from which they had been detached; and in turning over the

soil to procure the loose fragments, the backs of the veins would be laid open and discovered. This is a process which is even now daily going on in mining districts, only with a different object: for having found an accidental stone of ore, the miner does not now dig over the earth on the surface, for the sake of these casual deposits; but reasoning from their appearance that a vein is near at hand, goes at once to work in order to find it.

If we allow that this account of the origin of mining be true, it ought to follow that those metals were most anciently worked, whose ores are most attractive in their appearance, most easily reduced into a metallic state, or such as are most usually found near the surface of the earth. As far as the English mines afford us the means of judging, all this may be asserted to be true. The tin of Cornwall was undoubtedly the first metal sought after in Britain, and probably the first article of commerce with other nations; and the ores of tin, from their great weight, indicate their metallic contents, and yield them to the simplest treatment with fire, and are still found at inconsiderable depths. It may also be observed, that the traces of the most ancient tin works exhibit no symptoms of their having been pursued, but in situations where the soil, with which it was mixed, could be easily and expeditiously removed; or where it

could be washed away by streams of water, conducted over it for the purpose, and which, by carrying off the lighter parts of the soil, laid bare the ores, which are kept from moving by their superior specific gravity.

This latter was an ingenious improvement upon the first ruder efforts, and is still the mode employed in many of the tin stream works; while there are numerous traces of these attempts accompanied by circumstances, which prove them of very considerable antiquity.

Lead is another metal, which not only is often found near the surface, but the ores exhibit to the eye the appearance of metal, and in general yield their contents to the heat of a moderate fire. This metal, therefore, was probably an object of pursuit in the early ages of mining.

Copper, on the other hand, is seldom found without penetrating the earth to considerable depths; and the proportion of metal in most of the ores is so small, that a certain progress in the arts of mining and smelting must be presumed to have been made, before it could have become an object of research. We believe this to have been the fact in most countries, as well as in this, where copper was certainly discovered by working mines in pursuit of tin or lead.

From the processes for finding and separating metallic ores from alluvial matter in which they were casually mixed, the next step was to procure them by digging out the veins themselves, and following them into the solid rocks in which they are formed. At first this could only have been done, where, by the elevation of the mountains, it was possible to work high enough for the waters to discharge themselves by conduits or adits from the works; and where the rock was not so hard but to yield to tools rudely formed, or perhaps to the agency of fire, which would, however, produce but a limited effect in most cases.

It was not until machines were applied to pump the waters, that the metals could be followed to any considerable depth, and not until gunpowder had furnished the means of splitting the hardest rock, that man was enabled to penetrate strata of every description that opposed his progress.

These inventions, therefore, form most important epochs in the history of mining; for, since mankind have called in the assistance of such powerful agents, neither the influx of constantly flowing water, nor the barriers which the most indurated rock can present, are obstacles in the way of the miner, where rich and productive veins of ore tempt the pursuit.

The first important era was the period in which the application of gunpowder to the purposes of mining took place, which happened in Hungary, or Germany, about the year 1620, and was first introduced into England at the copper-mine at Ecton, in Staffordshire, about the year 1670, by some German miners brought over by prince Rupert. It was in use in Somersetshire about 1684, and it was not until after this period, probably, that the Cornish miners became acquainted with this powerful assistant to their operations.

Its importance may be judged of by the amount of the present consumption in the mines of Cornwall alone, which has been calculated at an annual value of about forty thousand pounds sterling.

There are many mines which could not possibly have been worked without the aid of gunpowder, and, until it was used, subterranean operations must have been difficult and very uncertain. The hammer and wedges were probably the first instruments employed for splitting rocks, and the pick followed, which is used both as a hammer and a wedge. The change of form in these instruments observed in those which have been found in old works, as well as the materials of

which they are sometimes made, offer evidence of considerable antiquity.

Many tools of oak have been occasionally met with, which tradition among the Cornish tanners make to have belonged to the Saxons or Danes, but it is probable that they were employed before the time of their having a footing in the country, and most likely when iron was little known here.

Wedges of dry wood were made use of by driving them into clefts of the rock, and then wetting them, so as to cause them to swell, and thus by repeated similar insertions to force the ground asunder.

Agricola describes the application of fire to the splitting of rocks, but there is no tradition of its having been applied to this purpose in England.

The means employed for raising or throwing up the ore and waste stuff to the surface, were at first as rude as the other operations of mining. The *windlafs* and *bucket* may be reckoned an improvement which took place in a later stage of mining, as simple a one as it certainly is, and now in a great measure superseded by more effective machinery. It was, however, at the time an important addition to the apparatus of mines, as water as well as ore could thus be raised to moderate heights; and by the employment of much manual labour with a number of such machines, even considerable excavations were kept free from water, and had their produce lifted to the surface.

The windlafs, probably, like most of the early improvements in mining, had its origin in Germany, and before it was introduced here from that country, the mode adopted for throwing up the stuff dug in the bottom of the deeper pits, was by making successive steps, or stages, which were called in Cornwall *shammels*; upon each of which men were placed, who raised the excavated matter from one to the other, until it thus reached the highest point.

In South America the windlafs is even yet hardly known, and the ores are either carried up by the Indians employed in the mines, or, where the situation admits of sloping roads being made to the bottoms, are conveyed to the surface on the backs of mules.

When mines were worked deep, the labour of raising the water which was constantly collecting, became too great for mere manual exertion, and hydraulic machines were invented or employed for the purpose. Pumps were adapted to the shafts, and their constant action secured by giving motion to their pistons by wheels turned by descending streams of water. Where supplies of this agent can be obtained, and the form of the country admits of its application with considerable falls, nothing better can be desired, as it is a more regular power than steam, and infinitely less expensive; it has, therefore, continued in use to the present day, where circumstances admit of its being applied.

The German miners seem in all probability to have had the merit of these inventions, as they appear to have been completely in use among them when Agricola wrote, who fully describes their construction and application.

But though Germany may fairly claim the invention of these engines for this purpose, yet nothing more has been done there; but, on the contrary, they are said to remain now there in nearly the same state as at their original introduction. The English miner has improved the pump-work and the water-engines to their present high state of perfection in this country.

It is in some degree owing to necessity that this has been the case, as there are single mines in England which require that as much water be discharged from them, as the pumps of a whole province of German mines could effect. There

is, indeed, no need to prove the capacity of English artists for mechanical improvement.

Hydraulic machines, however, as they require falls of water to put them into motion, can only be erected where the circumstances of a country afford the means of working them; and if nothing further had been done, many of our most valuable mines in Cornwall, not to mention our collieries and lead mines, would have remained unexplored and unproductive. The invention of the *steam-engine* gave to the miner a power capable of universal application, and of an effect that added, as it were, new regions of subterranean country to his controul. Depths hitherto unattainable are now placed at his command, and no limit can be assigned to his exertion, but that of the expence compared with the value of the produce.

The history of the steam-engine will be a subject for another place; but we may here observe, that the invention very early excited the attention of the mine owners of Cornwall, who successively adopted and encouraged the improvements of Savary, Newcomen, and Watt.

In this district some of the earliest efforts of these ingenious men were seconded and rewarded, and in return the mines have gained such assistance as could not have been formerly anticipated or imagined.

The general history of mining in England has never been very accurately traced; the districts famous for their mineral products have no communication with each other on this account, and have no common mineral laws or customs.

In other countries mining has been fostered and protected by the state, immunities have been granted, the workmen have been surrounded by particular privileges, and their operations encouraged by grants of timber from royal forests, or the free use of lands and waters. Thus peculiar systems of laws have often arisen where the mines were important as a source of revenue to the state. Something of this sort is indeed to be traced in the stannary laws of Cornwall; these laws, however, are not operative in the other mining districts of England, but are confined to the counties of Devon and Cornwall, which are both included in the royal duchy which bears the name of the latter. Here the stannary laws still existing, now afford the miner but scanty assistance, though they effectually provide for the secure payment of the mineral revenue to the duke of Cornwall. To this object, and to the adjusting disputes touching the affairs of tin mines, the present administration of these laws may be said to be directed. The protection to the person of the tinner, as to military service and processes from other courts, has been gradually removed, and the rights of embounding lands for his pursuits, and of obtaining water-courses for his engines, have been questioned, and, in some cases, rendered doubtful. It cannot, perhaps, be contended that these laws could now be exercised in their former construction in the present state of property; but a revision, accommodating them to the fair wants of the miner, without prejudice to the land owner, would be attended with much benefit to the mining interest.

The copper-mines, being altogether of later date than those of tin, partake of none of the advantages which the stannary laws afford, and are therefore governed more by custom than any thing else; an extension of the privileges of the tin mines to these, and a legal provision for the peculiar arrangements which such undertakings require, would remove many serious obstacles to their prosecution.

Mining in England had a very early origin, compared with the progress of other arts in the country; it was in all probability the first source of trade to these islands, and the tin of Britain was known in distant parts of the world at a very remote period. It is generally believed that the Phœnicians were the nation principally engaged in trading to

Britain for this metal. Tin works were carried on before iron was in use in England, as may be presumed from the tools of oak which have been found in ancient mines. Cicero affirmed that no silver was to be found in Britain, and though it has since been proved that he was wrong in that respect, yet the notice taken of the subject serves to shew that the metals of the country were the principal temptation to the Roman conquerors.

The Saxons neglected the pursuit of the metals, but the Normans appear to have worked for them to advantage, and from this time, until the reign of king John, the mines were mostly in the hands of Jews, when they are said not to have been successful, but in the reign ensuing they were worked by the same people with more effect. Edward I. caused the Jews to be banished, and the mines were, in consequence, neglected, until Edmund, the elder son of that king, and earl of Cornwall, willing to restore what had produced so large a proportion of the revenues of his domain, made grants important to the miner, which were confirmed by the king, by a charter in the 33d year of his reign; which states that

“For the advancement of the stannaries, he frees the tinnors from all pleas of the natives touching the court, and from answering before any justices, &c. save only the keeper of the stannaries; (pleas of land, life, and member excepted) neither are they to be kept from work but by the said keeper.” And it further “indemnifies them from tolls, &c., gives them libertie to dig tin and turf any where in the said countie, and to turn water-courses for their works at pleasure; with many other privileges.”

It is from this time that the enactment of laws for the government of the stannaries may principally be dated.

Power to search for other metals besides tin was granted to individuals immediately from the crown, and we find that various persons held the right of searching for mines in the reigns of Edward III. Richard II. Hen. IV. and Hen. VI. In some of these grants, gold, silver, and copper are mentioned as well as lead.

The privileges of the tinnors were not interfered with by any question relating to these metals, nor, on the other hand, did the jurisdiction of the stannaries extend to affairs connected with them.

Thus we find an appeal to the exchequer in the reign of Henry VI. relative to lead mines. *From the records, Easter term, anno 36. Regni. Devon Memorand.* “That John Bottwright, governor of the mines of Bury Ferrers in Devon, complains to this court that Robert Glover, at the command of Roger Champernown, took away 144 boules of glance oar, valued at 15*l.* 6*s.* 8*d.* and made profit of the same without any thing allowed to the king, to the king's damage of 100*l.* and thereupon desireth the advice of the court.”

The mines continued to be protected by the crown, and particularly by Henry VII., until Edward VI., when they were neglected; and fell into complete decay during the disastrous government of Mary.

When Elizabeth succeeded to the crown, the mines of the kingdom partook of the attention which this enterprising queen bestowed on every object from which an increase to the resources, or an addition to the strength of her government, might be derived.

The failure of the mines had diminished the number, and annihilated the skill, of the English miners; the queen therefore invited over Germans, and made extensive grants in different parts of England to Houghsetter and Thurland, and likewise others to William Humphreys and Christopher Shutz. She also established, in 1568, a corporation, which still exists, called “The Society for the Mines Royal,” which had certain grants and privileges in several counties, and of

which William, earl of Pembroke, was the first governor. It does not appear that this society, which was originally a mining company, though now engaged in smelting ores only, produced any important effect upon the discovery of metals in England; the tin mines of Cornwall were not worked by them, but remained in the hands of private adventurers, under the jurisdiction of the stannaries, and increased in produce and value in proportion to the demand for this metal. The whole amount of tin annually raised in Devon and Cornwall, in the following reigns of James I. and Charles, was from fourteen hundred to sixteen hundred tons. It is probable that the civil wars which succeeded injured the workings of the mines, as in the reign of Charles II. it appears from a note of Mr. Scawen, of Molineck, who was vice warden of the stannaries, and quoted by Dr. Pryce, that the tin revenues were very small.

In the reigns of Anne and George I. the produce of tin had again become considerable, and amounted, one year with another, to something more than sixteen hundred tons; so that in the space of 110 years its mean proportion was equal to fifteen hundred tons *per annum*.

Since the foregoing time a gradual increase took place in the ensuing thirty years; for in the year 1742 a proposal was made by the Mines Royal Company in London to raise one hundred and forty thousand pounds to encourage the tin trade by farming that commodity for seven years at a certain price. A committee of Cornish gentlemen were appointed to consider of the proposal; and they reported, "That the quantity of tin raised yearly in Cornwall, at an average for many years last past, hath been about two thousand one hundred tons;" and resolved, "That three pounds nine shillings for grain tin, and three pounds five shillings *per* hundred

weight for common tin, are the lowest prices for which such tin will be sold to the contractors, exclusive of all coinage duties and fees."

The produce of the tin mines was much more considerable afterwards, and from 1760 to 1780 it was reckoned at about two thousand eight hundred tons a-year, which was worth the annual sum of about 180,000*l*.

Copper began to be worked in Cornwall in the beginning of the 18th century, and the amount had attained at the period just quoted to about the same annual sum of 180,000*l*, making the mineral returns of this district at this period, *viz.* about 1780, to be of the yearly value of 360,000*l*.

The tin mines have not been so important to the Cornish miners since the discovery of copper as they were before, the produce of the latter having increased most rapidly, while the former have not made any proportional progress. As the subject is very interesting in estimating the power of this country to supply raw materials for its numerous manufactures, we shall give statements of the produce and other particulars of the tin and copper mines of Cornwall and Devon, from the early part of the last century to the present time.

We shall first state the produce of the tin mines, and afterwards give a more detailed account of the effect of the discovery of copper on the mining interest as well as the trade of the country.

The chief part of the tin in the following statement was produced from the mines of Cornwall alone, as although Devon had anciently yielded a large proportion of tin, yet before this period the mines, or rather the stream works of the latter county had become exhausted, and were incapable of producing any notable proportion of ore.

Account of the Quantity and Value of Tin raised in Cornwall and Devon, from 1700 to 1800.

Dates.	Number of Blocks 6½ to a Ton.	Number of Tons.	Price <i>per</i> Ton.	Periods.	Annual Quantity in Tons.	Annual Value.
			£. s. d.			£. s. d.
1700 to 1720	208,000	32,000		20 years	1600	
1720 to 1740	273,000	42,000	66 0 0	20 years	2100	138,600 0 0
1740 to 1750	162,500	25,000	65 0 0	10 years	2500	162,500 0 0
1750 to 1760	172,779	26,580	63 7 6	10 years	2658	168,450 15 0
1760 to 1770	177,302	27,277	66 6 8	10 years	2728	180,957 6 8
1770 to 1780	178,737	27,498	60 2 0	10 years	2750	165,275 0 0
1780 to 1790	192,295	29,583	68 2 0	10 years	2958	201,439 8 0
1790 to 1800	210,928	32,450	73 1 0	10 years	3245	227,047 2 6

From this table we may observe a regular increase in the quantities raised, the improvements in mining which took place having contributed, without doubt, to produce this effect. The price of the metal did not advance in proportion to the increase of the charges on labour, and the enhanced value of the articles used in the mines, and therefore we cannot account for the greater produce from increased demand, but from the power derived by improved means of working, and thus of bringing the metal to market at a cheaper rate. About the year 1770 the quantity raised appears to have been greater than the demand required, and the price seems to have been lower than at any former period, which was probably likewise affected by the war, and by the influx of tin imported into Europe by the Dutch from their possessions in the East Indies, where it is raised as well as in England. The advance in price that followed in the next period, may be attributed to the revival of trade, in consequence of the

peace which followed the American war, but this again produced an over quantity in the market, followed by a depression in value, very injurious to the miners, which was severely felt about 1789, when, by the exertions of Mr. G. Unwin, an export of tin to China, through the East India company, took place, that absorbed the surplus which the European market did not require, and thus the price advanced again to a rate higher than any preceding one. This export to India has continued ever since, and may probably increase notwithstanding that tin is found in some considerable quantity in Asia.

From 1800 to the present time the tin mines of Cornwall have rather declined, and are probably gradually exhausting, this metal not being found to penetrate so far into the earth as copper, and therefore but few mines have been found to continue productive at very considerable depths.

Any decline that may have taken place in the tin mines of Cornwall has, however, been more than compensated by the

rapid advances which the copper mines have made in that and the neighbouring district, which of late years have been so great as to render them of the highest consideration, and to give these concerns the precedence over all similar undertakings of any country. For whether we consider the quantity of their produce, the immense capitals invested, the power and number of their engines, the skill with which they are conducted, or the spirited and rapid execution of the works, they will probably be found to take the rank here assigned to them.

Cornwall possesses many eminent advantages as a mining country, of which its maritime situation is among the most important, but another is that it is peopled by a race of men peculiarly fitted for this employment. The Cornish miners unite great courage to personal strength and activity, while we may observe in their character intelligence mixed with persevering enterprise, and patience of fatigue with a considerable independence of spirit.

There is no doubt but that the system of management adopted in the mines, which long usage has matured into a system as beneficial to the mine owners as stimulating to the exertions of the workmen, has tended much to render the latter what they now are, though their insulated situation has likewise probably preferred to them much of their original character as a people.

With such advantages, and with a sufficient quantity of the metallic ores distributed throughout it, a district only requires capitalists of sufficient wealth, intelligence, and enterprise, to render it of consequence as a mining country, and it has happened to Cornwall to have gentlemen possessed of all these requisites.

The statements which follow will shew how the discovery of a valuable metal has been followed up, and an intimate acquaintance with the Cornish mines would prove how great the exertions must have been, to have produced effects in a short time which the labour of ages in other countries have scarcely equalled.

We have before observed that copper began to be sought after in Cornwall about the beginning of the eighteenth century, and, as might be expected, we have no exact accounts of the success of the undertakings for its pursuit in their earliest stage. In a few years, however, the quantity produced had attained to a considerable amount, and we shall be enabled to trace pretty accurately the progress afterwards made.

The first document on the subject is the following:
Statement of the Returns of Copper Ores in Cornwall, from 1726 to 1775.

Years.	Tons of Ore.	Average Price per Ton.	Amount.	Annual Quantity of Fine Copper.
		£ s. d.	£	(Probably)
1726 } to 1735 }	64,800	7 15 10	473,500	700 Tons.
1736 } 1745 }	75,520	7 8 6	560,106	830
1746 } 1755 }	98,790	7 8 0	731,457	1080
1756 } 1765 }	169,699	7 6 6	1,243,045	1800
1766 } 1775 }	264,273	6 14 6	1,778,337	2650

This account is taken from Pryce's "*Mineralogia Cornubiensis*," excepting the last column of the quantities of metal produced from the ores, which it was desirable to exhibit, in order to compare the increase of late years, of which the quantity of *fine copper* is the only true criterion, the ores often differing materially in their metallic content. The statement is, however, given as respects this part of it only as a near approach to the truth, as we have no certain data to calculate from; the assay and price of copper, by which the value paid to the miner was determined, being in a great part of the period above quoted not easily ascertained. The amount of metal is, however, calculated from the most probable supposition.

From the table we see, that in Cornwall the produce of copper increased in fifty years from about 700 tons of fine metal *per annum* to 2650 tons.

Copper mines were not attended to in England much before the dates in the preceding table, the discovery of this metal probably having taken place in working the tin mines, which had been wrought time immemorial. Soon after that discovery, in 1691, a charter was granted to Sir Joseph Herne and others, merchants of London, who were thereby incorporated as a company for the purposes of refining and purifying copper ores.

This company still exists, and is now commonly called the English Copper Company.

The Mines Royal Company, which had been incorporated near 100 years before this time, appear originally to have designed to apply their resources to the opening and working mines in various parts of the kingdom, and they had grants for searching for copper among other metals, although it does not appear that any important discovery of this metal took place in consequence of their exertions, nor is mining one of those pursuits which is ever likely to flourish in the hands of large companies.

In 1694, a copper coinage of halfpence and farthings took place, and government paid at the rate of 18*d.* a pound for the copper, which was of Swedish produce.

In 1717, a further coinage took place, to the amount of 700 tons of English copper, for which government paid at the rate of 15*d.* *per* pound, or 147*l.* *per* ton.

In 1702, the first brass work in England was erected near Bristol, which has continued to this time, but with great additions and improvements. Many other copper and brass houses have been since erected in this country, and by that spirit, energy, and enterprise, for which the people of it are so distinguished above all others, the most valuable branches of the copper and brass trade have been established in England, which had before been altogether, and for ages, carried on in Germany and Holland.

For the first twenty or thirty years of the last century, and always before, most of the copper and brass utensils for culinary and other purposes of this country were imported from Hamburgh and Holland, procured from the manufactories immemorially established at Nuremberg and various other parts of Germany; even brass pans for the purposes of the dairies of our country could not be procured but of the German make.

So late as 1745, 1746, and 1750, copper tea-kettles, saucepans, and pots of all sizes were imported here in large quantities from Hamburgh and Holland; but through the persevering industry, capitals, and enterprising spirit of our miners and manufacturers, these imports became totally unnecessary, being all made here, and far better than any other country could produce.

During all this time the price of copper will be found to have been as high as it has been in the last three or four

years, 1808, 1809, 1810, and 1811, notwithstanding the great difference in the value of money, and consequent advance of price on materials used in mining, and of the wages of labour employed therein.

It appears above that government paid for copper used in their coinages in the year 1694 at the rate of 18*d.* a pound, or 168*l.* a ton for metal the produce of Sweden; and in 1717, they were supplied with English copper at the rate of 15*½d.* a pound, or 147*l.* a ton.

The reduction here specified in value may fairly be accounted for by the increasing produce of the English mines, and accordingly the price went on to lower nearly in proportion to the quantity which was thus brought into the market.

In the year 1720 copper was sold for about 130*l.* a ton, and declined towards the year 1772 to the price of 100*l.* a ton.

About the year 1773, new copper mines being discovered in Derbyshire and Wales, and fresh supplies of fine copper coming from thence to market in competition with the Cornish copper, the price of it fell gradually until 1781. In this year the East India company first paid so little as 79*l.* a ton for cake copper. This great reduction was owing to a warm contest which took place between the owners of the Cornish mines and those of the Paris Mountain mine in Anglesea, which had become amazingly productive, and so as to alarm the fears of the former.

Arrangements were afterwards made between the parties principally concerned in the mines of these two districts, by which the price was somewhat advanced, but did not exceed at any time 84*l.* a ton, and continued at nearly the same rate until the year 1791.

By this time England, instead of depending upon foreign mines for a supply of copper, had become one of the principal sources from which the world at large was furnished with this useful metal.

Accordingly, in the year 1791 we find that the exports of different articles in which copper either formed the whole or the principal ingredient, amounted to a very considerable branch of trade, and that these articles went in large quantities to those very countries upon which England had formerly depended for a supply. Among these may be noticed Holland, Germany, and even Sweden itself.

The total exports were, in 1791,

	Tons.	C.	qrs.	lbs.	£	s.	d.
Wrought copper	3082	3	3	11	value 358,844	9	1
Brass and plated goods	2324	2	0	11	209,769	8	9
	5406	5	3	22	568,613	17	10

Comparing this with the produce of copper in Cornwall in the year 1775, as above quoted from Dr. Pryce, which was only 2650 tons, and allowing for what might be brought to market from Anglesea, we may, in some measure, judge of the increase in the quantity of metal from the Cornish mines in this period of sixteen years, even under the discouraging circumstance of great competition and reduced prices.

Besides this vast export, a new source of consumption for copper had in the mean time arisen at home in the use of it very extensively in sheathing and fastening ships, and this alone would require considerable quantities.

The demand having apparently kept pace with the quantity brought to market, the question will naturally be asked, how it happened that the price continued to fall, or at least to remain at a rate so much under what it brought 100 years before? Though the answer to this question must include other considerations than those connected with mere mining, it may be proper to go a little out of our way to answer it, particularly as it relates to the mines of Corn-

wall, which were at one time threatened almost with ruin, from the value of their produce not bearing any proportion to the increase in their expences, from the diminished value of money, and the rapidly accumulating charges occurring from the great depths to which most of the productive mines were by this time worked.

The reason, then, of the price of copper not bearing a proportion to the cost of procuring it, and the demand of the article, appears to have been simply this. Neither the miners nor the great consumers of the copper were smelters of the ore; but this business was in the hands of a very few companies, employing immense capitals in their works, who thus had the power of managing the market, and of preventing that salutary competition, which alone can regulate fairly the due course of trade.

The principal smelters, by a contract which had been entered into improvidently with them by the majority of the miners, had possessed themselves of the greater part of the copper ores of the county of Cornwall at a fixed price; and this price being found inadequate to meet the increasing charges of working the mines, discontents arose, which spread among the labouring miners, who feared the loss of their employ by the ruin of the mines, which was anticipated. Many of the proprietors, or adventurers as they are usually called, who were not personally parties to the contract, refused to be bound by the act of their co-adventurers, and considerable confusion ensued.

The small proportion of the ores, not included in the contract, continued to go to public sale, where the price was advancing; but these sales were attended by a few smelting companies only who had not joined the others, until the following circumstance occurred, which materially contributed to open a free market to the miner for the sale of his ores, upon a plan that ensures a fair and equitable price, according to the demand, as far as is possible, where the number of buyers must be necessarily small.

Many of the principal manufacturers of Birmingham, who were large consumers of copper, had observed the difference between the price of the metal in the ore paid to the miner, and the price at which they bought it when smelted. They saw no other reason for the intervention of a third party between the miner and consumer, but the capital necessary for the erection of smelting works; and this being easily raised by shares, a company was formed under the name of the Birmingham Mining and Copper Company: their object being to encourage the production of copper, by adventuring in the mines, as well as to procure it for their manufacture, by purchasing and smelting the ores.

As soon as the company was established, they proposed to revive the old mode of the sale of ores, which had, owing to the contract, nearly fallen into disuse, called a *ticketing*; by which, on certain days, the ores of any number of mines, being previously sampled and assayed, are offered for sale by tenders or tickets, produced by the agents of each smelting company, and delivered to the chairman of the meeting which is held for the purpose, who declares the offer of each, and the highest the buyer.

This revival of the ticketings was effected by the Birmingham company joining the small number of smelting companies who were not concerned in the contract, and the competition was rendered complete. A new spirit was infused into the working mines, by an increase of the price of their produce. Other smelting companies were afterwards formed upon similar principles; and the demand for copper advancing rapidly, while the quantity produced in Anglesea and other parts of England lessened, the mines of Cornwall flourished in proportion.

The advance on copper began to be felt about 1792, when it had attained the price of 100*l.* per ton; and in a very few years after (1799), it had reached 124*l.*: being still, however, much lower than it was in the beginning of the 18th century.

We may recollect that the quantity of copper raised in Cornwall, in the year 1775, was about 2650 tons a-year: in 1789 it had increased to about 3000 tons; which increase was progressive, as in the year 1797, according to the report laid before the house of commons, the quantity amounted to 5093 tons; and in the following year (1798), was 5427 tons.

So that we see in the period of about 70 years from 1726, the annual quantity produced by this district had risen from 750 to 5427 tons; and that the aggregate amount of an article, valuable as a raw material, affording, after it passes from the hands of the miner, the means of subsistence and profit to thousands, had risen from the sum of 47,350*l.* to about 600,000*l.* a-year. Even this great increase of produce was far exceeded in the course of the next eight or nine years, when, as we shall see hereafter, half as much more was added to the quantity, and more than that proportion to the value.

Early in the year 1799 the Birmingham manufacturers, finding the price of copper rapidly increasing, began to be alarmed lest a diminution of their trade should be the consequence, and having apparently overlooked the plain rule of commerce, that, without unfair restraint, demand must govern price, applied to government to impose prohibitions on the export, and other regulations, which would have amounted in effect to the fixing a maximum on the price, and consequently a ruinous restraint on a valuable source of national wealth, and laudable enterprise and exertion. It may be justly wondered at, that any ministry should have listened to such a proposal; but great as were the boasted talents of the then premier, he appears to have been led to the warm support of it, by the narrow consideration which was held out to him, of supplying the navy with copper at a somewhat lower price; not looking forward to the probability that any step which might ruin the British copper mines, must eventually make the British navy dependent on other countries for this essential article of equipment.

The contest that ensued between the miners and the manufacturers produced many curious documents, which were laid before the committee of the house of commons appointed to investigate the subject, and from which we are now enabled to state particulars of the mines of Cornwall, more exactly than could have been obtained, had not such an occasion called them forth.

The matter came fully before parliament, the good sense of which defeated the impolitic wishes of the proposers of the restrictions, and left a ministry unaccustomed to defeat in a minority on the question.

That the predictions of the manufacturers were groundless may be inferred from what took place afterwards: the price of copper advanced 50 *per cent.* in the next seven years, and the Birmingham trade, notwithstanding, increased in activity and consequence. The high price stimulated the enterprise of the miner, until an over-supply began to operate; and in the last few years, this, together with the unfortunate state of foreign trade, has again reduced the price of copper, so as once more to endanger the existence of a great proportion of the copper mines.

From the documents before alluded to, we find that, in February 1799, there were in Cornwall then working sixty copper mines, which were divided into classes, to shew their relative conditions. The accounts are made up for the six months preceding the statement.

Class 1. Includes the old deep mines, which produced in the six months more than half of all the copper raised in Cornwall.

2. Includes the profitable mines, which produced about three-eighths of the copper.

3. The new mines which were carrying on in the hopes of their improvement, and the greater number of which, in fact, had not begun to yield any ore.

The result of the statement is as follows, in which it is to be observed that the value of the ores is accounted for, after deducting the proportion paid to the owner of the soil, and therefore does not exhibit an account of all that was raised. The first column of loss refers to the money sunk in the six months for which the account is taken; and the last column of unrecovered loss includes all the money laid out from the commencement of each mine, which had not been paid off by adequate returns.

State of the Copper Mines of Cornwall for six Months, to the end of February 1799.

	Quantity of fine Copper.			Adventurers' Amount of the Value.			Cost of working the Mines.			Total of Profit on some Mines.			Total of Loss on others.			Capital employed in the Mines.			Unrecovered Loss.		
	Tons.	C.	q. lbs.	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.
Class 1.—Including ten old and deep mines	1388	3	1 21	115,121	13	10	116,209	1	6	3153	0	3	4240	7	11	102,489	0	0	69,181	2	10
Class 2.—Seven profitable mines	1083	12	2 24	86,377	15	3	49,311	11	1	37,066	4	2				66,813	0	0	5483	17	2
Class 3.—Forty-three new mines, of which thirteen only had begun to raise any ores	141	17	1 13	14,517	13	3	31,813	5	9				17,295	12	6	16,267	0	0	90,124	16	8
	2613	13	2 2	216,017	2	4	197,333	18	4	40,219	4	5	21,536	0	5	185,569	0	0	164,789	16	8

By this statement we see, that the total profit of the six months, in all the mines, exceeded the loss by the sum of 18,683*l.* 4*s.* 0*d.*, and in the loss is included a considerable amount, which it does not seem clear should have been placed there, *viz.* the sums expended on the new mines in the period, as this may more properly be called an investment of capital with a view to future expected profit.

The unrecovered loss is subject to the same remark, though it is usual to reckon in mining the expenditure as loss until the profits have repaid it. The capital, however, which means the value of stock upon the mines, ought to be deducted from this unrecovered loss; and if this be done, and a fair allowance be made for the value of such new mines as might have been supposed likely to become profitable, the

account gives no unfavourable impression of the general result at that time.

Another observation may be made on this account which seems necessary, as it does not appear on the face of it. Credit is only given for the adventurers' part of copper ores; but several of these mines returned tin as well as copper, of which no account is taken, and which must, in all probability, have increased the profits of the six months, if stated.

The next table shews the general receipts and disbursements on the copper mines of Cornwall for seven years, ending the 31st December, 1798, which cannot be deemed so favourable as the former, which related to the latter part of this same period.

General State of the Copper Mines of Cornwall for Seven Years, ending the 31st of December, 1798.

Years.	Adventurers' Amount of Ores.			Labour.			Materials.			Total Cost.			Profit.			Loss.		
	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.
1792	279,331	15	10	150,824	12	3	91,361	6	4	251,865	19	11	27,465	15	11			
1793	283,853	12	11	176,333	2	7	110,122	15	2	294,226	15	0				10,373	2	1
1794	293,853	10	11	179,187	15	5	111,093	19	11	294,775	19	5				922	8	6
1795	305,320	6	9	189,713	10	1	111,640	2	3	312,047	7	5				6727	0	8
1796	348,836	12	11	201,995	18	6	105,925	12	1	324,897	18	4	23,938	14	7			
1797	320,606	15	9	189,821	15	11	109,008	7	3	309,060	14	10	11,546	0	11			
1798	405,488	15	9	253,601	12	3	146,253	16	3	408,248	7	11				2759	12	2
	2,237,291	10	10	1,341,478	7	0	785,405	19	3	2,195,123	2	10	62,950	11	5	20,782	3	5

N. B.—The columns of labour and materials, added together, do not make up the total cost, because the accounts sent from some mines do not distinguish the amount of labour from materials; and, therefore, could be no otherwise arranged than by being carried at once to the column of total cost.

The average annual cost of working the copper mines of Cornwall for this period appears to have been 313,589*l.* Out of this sum the labour appears to have cost about 197,640*l.*, and the materials employed about 115,950*l.* The proportion of the one to the other being nearly as 5 to 3.

The great amount of the latter may be attributed to the great depth of many of the mines, whereby the charge for coals for the steam-engines, and the wear and tear in the shafts of cordage and other articles, is prodigiously increased.

If, taking the amount of labour at the above sum, we allow 40*l.* as the annual earnings of each man employed, which is nearly the usual proportion, we shall find it would shew that there are about 5000 men employed. But as a certain proportion belongs to the boys working under ground, and the women and children who dress the ores on the surface, who altogether are paid after a much lower rate, the whole number of hands, including men, women, and children, may

not, at this period, perhaps be over-rated at from 6 to 7000.

In order to shew the respective state of each mine at this time, we insert the following table, which exhibits the name of each, with the particulars of their expenditure and returns, as far at least as copper is concerned; for, as was remarked before, no notice is taken of the tin produced from any of them.

We take the year 1798, the last of the seven years to which the statement given above refers to.

Such is the fluctuation of concerns of this sort, that at the present time, 1812, very few of those which appear at the head of the following list as most important in consequence and produce, are now working to much extent, while others, which either then lay neglected, or in which discoveries had not been made, have succeeded to supply their places.

State of the Copper Mines in Cornwall for the Year 1798.

Mines.	Adventurers' Amount of Ores			Labour.			Materials.			Total Cost.			Profit.			Loss.		
	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.
North Downs -	52,388	14	6	33,350	2	1	18,890	19	9	52,241	1	10	147	12	8			
United Mines -	36,194	8	4	20,196	0	3	20,241	19	3	40,437	19	6				4243	11	2
Consolidated Mines	35,613	11	10	21,547	4	2	13,877	14	0	32,424	18	2	3188	13	8			
Herland -	29,233	10	9	16,922	2	0	13,789	11	6	30,711	13	6				1478	2	9
Stray Park and } Wheal Gons }	12,125	10	10	6660	11	0	3182	13	0	9843	4	0	2282	6	10			
Poldice -	6993	19	9	4945	19	3	5677	3	1	10,623	2	4				3629	2	7
Wheal Unity -	41,330	8	7	10,851	2	5	13,510	17	10	24,362	0	3	16,968	8	4			
Crenver and Oat- } field }	19,429	14	7	9392	10	2	10,016	9	11	19,409	0	1	20	14	6			
Wheal Treasury -	19,978	4	10	20,050	18	8	5541	4	2	25,592	2	10				5613	18	0
Cook's Kitchen -	18,098	5	4	16,102	2	4	3468	13	7	19,570	15	11				1472	10	7
Wheal Rock -	995	19	7	1533	5	6	417	10	4	1950	15	10				954	16	3
Tin Croft -	35,242	17	1	15,233	10	2	6105	4	3	21,338	14	5	13,904	2	8			
Trefavean -	7609	2	9	5437	1	9	3069	2	3	8506	4	0				897	1	3
Prince George -	12,538	16	5	9045	3	5	1068	4	0	10,113	7	5	2425	9	0			
Camberne Vean -	6456	17	3							2885	1	2	3571	16	1			
Wheal Jewel -	19,035	18	2	10,710	6	8	5311	3	3	16,021	9	11	3014	8	3	12,796	17	11
Pednandrea -	5078	7	10	10,587	16	8	7287	9	1	17,875	5	9						
Wheal Fortune -	20,767	0	3	9450	18	7	2560	13	10	12,011	12	5	8755	7	10			
Wheal Gorland -	9032	0	8	3975	17	0	1893	19	5	5869	16	5	3162	4	3			
Wheal Providence	257	8	0							252	7	4	5	0	8			
Wheal Hope -				400	3	6	247	9	6	647	13	0				647	13	0
Scorrier -	102	14	6	509	10	6	103	14	7	613	5	1				510	10	7
Cherry Garden -	22	13	9	321	3	0	56	11	11	377	14	11				355	1	2
Wheal Susan -	1407	8	9	1956	13	0	1465	1	8	3421	14	8				2014	5	11
Wheal Squire -										820	3	7				820	3	7
East Wheal Spar- } non }				356	6	3	45	10	5	401	16	8				401	16	8
Drollas Downs -	1075	14	7	1847	5	11	41	19	2	1889	5	1				813	10	6
Wheal Captain -	643	9	9							1617	16	7				974	6	10
Creegbraws -	77	3	10	1054	7	3	154	18	6	1209	5	9				1132	1	11
West Wl. Unity -										83	19	9				83	19	9
Wheal Penrose -				108	6	8	12	0	2	120	6	10				120	6	10
Wheal Tremayne -				127	14	5	2	19	0	130	13	5				130	13	5
Wheal St. Aubyn -				53	19	10	15	1	3	69	1	1				69	1	1
Rose Lobby -				270	7	8	138	9	5	408	17	1				408	17	1
Heart's Eate -				273	13	8	4	19	10	278	13	6				278	13	6
Bosprowall -	1377	11	3	1413	1	0	398	5	2	1811	6	2				433	14	11
Druid -	17	18	11	421	12	4	264	5	1	685	17	5				667	18	6
Wheal Fanny -				640	16	4	468	19	6	1109	15	10				1109	15	10
New Roskeir -	475	19	3	1106	9	3	1280	1	2	2386	10	5				1910	11	2
Polgine -										1220	3	9				1220	3	9
Wheal Christoe -				43	7	10	10	19	0	54	6	10				54	6	10
Wheal Drim -										56	16	5				56	16	5
Dopps -	15	10	0	241	12	7	31	9	10	273	2	5				257	12	5
Nanjiles -				71	3	7	18	18	0	90	1	7				90	1	7
West Downs -				612	2	10	187	13	2	799	16	0				799	16	0
Wheal Abraham -				1618	11	5	815	18	5	2434	9	10				2434	9	10
West Good Success				156	12	2	34	7	9	190	19	11				190	19	11
Whitefield -				418	3	6	198	5	4	616	8	10				616	8	10
Wheal Pink -										118	18	9				118	18	9
Penfstruthell -				195	11	2	33	18	7	229	9	9				229	9	9
Wheal Damfel -				373	14	5	101	16	5	475	10	10				475	10	10
Wheal Quick -	121	17	7	537	9	5	204	13	2	742	2	7				620	5	0
North Good Success				81	0	5	1	6	7	82	7	0				82	7	0
Carried over	393,738	19	6	241,203	12	0	139,250	5	1	387,509	4	5	57,446	4	9	51,216	9	8

Mines.	Adventurers' Amount of Ores.			Labour.			Materials.			Total Cost.			Profit.			Loss.		
	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.
Brought over	393,738	19	6	241,203	12	0	139,250	5	1	387,509	4	5	57,446	4	9	51,216	9	8
Wheal Bounty -				122	9	10	61	11	4	184	1	2				184	1	2
Wheal Rachel -				123	6	5	20	1	9	143	8	2				143	8	2
Wheal Royal -										66	16	1				66	16	1
Wheal Clinton -				60	2	0	38	9	8	98	11	8				98	11	8
Tolcarne -	641	6	1	1248	0	9	532	12	4	1780	13	1				1139	7	0
West Tolcarne -	13	4	8	98	3	2	24	13	8	122	16	10				109	12	2
Wheal Union -				102	14	0	20	10	6	123	4	6				123	4	6
East Wheal Vogue				71	15	4	17	3	0	88	18	4				88	18	4
Wheal Spinfster -				36	2	6	4	5	4	40	7	10				40	7	10
Trefkerby -				111	8	4	14	16	3	126	4	7				126	4	7
Cardrew -	30	2	6	212	2	0	23	14	0	235	16	0				205	13	6
Wheal Leeds -	39	6	4	430	19	9	447	11	5	878	11	2				839	4	10
Trenethick Wood										685	6	5				685	6	5
Wheal Nuttrall -	639	9	8	641	17	8	18	2	11	660	0	7				20	10	11
Trefkow -	7495	14	8	5375	19	8	2576	18	10	7952	18	6				457	3	10
Penberthy Crofts	281	2	9	1912	0	6	686	8	3	2598	8	9				2317	6	0
Wheal Kayle -				135	17	3				135	17	3				135	17	3
East Wheal Park				345	5	6	160	6	0	505	11	6				505	11	6
Wheal Ruth -				136	9	5				136	9	5				136	9	5
Wheal Carpenter										53	1	11				53	1	11
Wheal Chance -										226	14	0				226	14	0
West Wheal Jewel	1551	17	5	1243	6	2	2356	5	11	3599	12	1				2047	14	8
Wheal Bog, ore and materials fold }	1057	12	2							295	13	7	761	18	7			
	405,488	15	9	253,611	12	3	146,253	16	3	408,248	7	10	58,208	3	4	60,967	15	5

About this period a part of the county of Devon began to attract notice as a mining district, although it might rather seem to belong to Cornwall, if a division had been made between the counties by a line that an observer of the geology would have chalked out, rather than by the arbitrary limit of a river. The mines of Devon may, therefore, fairly be ranked as a branch of the great mineral country adjoining, as their features are nearly alike, the products very similar, and the system of working derived from Cornwall. A space of no inconsiderable extent indeed is to be found lying between the western and most considerable mines in Cornwall, and those on its eastern limits, which intervening tract is comparatively unproductive in mineral treasures.

The tin mines of Devon have been before alluded to, and we have seen that they had gradually declined into insignificance. Copper had now been found, and pursued with some success, and though the quantity was not very great at this period, it soon led to greater exertion, which in turn was repaid by the discovery of new mines and an enlarged return of valuable produce.

It is probable that before 1800 the mines of Devon, which are mostly situate within a few miles of the town of Tavistock, did not yield more in any one year than about 100 tons of fine copper, and even this was a very recent discovery; we shall now see that they went on, together with those of Cornwall, augmenting in importance.

From 1798 to 1804, the produce of the Cornish mines appears to have continued pretty steadily at about 5500 tons of fine copper a-year; while the Devon mines in the same period increased their returns very rapidly, which had reached, about this time, to about 300 tons of fine copper a-year.

The price of the metal we mentioned to have been, in 1799, about 124*l.* a ton, and until 1804 a gradual increase was experienced, although the supply was at least somewhat larger. In the following year, however, owing to the flourishing state of the export trade, the value of copper rose very rapidly, and reached the unprecedented price of 180*l.* a ton to the miner. The consequences of this were soon felt, and, by the exertion produced by this stimulus, the returns of the Cornish and Devon mines reached to more than 7000 tons of fine copper, fetching, at the first hand, the sum of 1,260,000*l.*

From this time to the present, the value of copper has experienced violent and rapid fluctuations, being, at one time, at half the price of the year 1805; and as this has proved a cause of great embarrassment and loss to the adventurers in the mines, so it has tended to reduce again the quantity of copper raised.

The year or two following 1805 were, as might be expected, even more productive than that in which the price attained its highest pitch, for the exertions it caused operated long after the price began to decline.

The following Table exhibits a Statement of the Quantity of Copper Ores and Fine Copper produced by the Mines of Cornwall and Devon during the last four Years, taken up to the End of June in each Year, and the Value calculated according to the Average Standard, or Miner's Price of the Metal.

		Copper Ores.			Fine Copper.				Average Standard per Ton.			Annual Amount after deducting Charges of Smelting.		
		Tons.	cwt.	qrs.	Tons.	cwt.	qrs.	lbs.	£	s.	d.	£	s.	d.
1808	Cornwall -	73,434	2	1	7118	5	1	17	107	0	0	781,348	16	7
	Devon -	3725	0	0	369	10	0	0						
1809	Cornwall -	77,159	2	1	7487	15	1	17	122	0	0	875,784	2	3
	Devon -	72,038	12	2	6972	17	0	24						
			3210	0	0	365	1	3						
1810	Cornwall -	75,248	12	2	7337	18	3	24	141	0	0	969,376	19	0
	Devon -	76,525	14	3	6651	18	2	5						
			3713	0	0	354	15	0						
1811	Cornwall -	80,238	14	3	7006	13	2	5	125	0	0	767,379	4	0
	Devon -	70,039	0	1	5948	7	0	22						
			3540	0	0	323	13	0						
		73,579	0	1	6272	0	0	22						

We have now brought the history of the copper mines up to the present period, and we have found what has been done in one district in the space of about 100 years after the discovery of the metal. We may observe, that in the beginning of the 18th century the annual produce of the mines consisted of about 6500 tons of ore, and 700 tons of fine copper, yielding to the miners, who, from their ignorance of the subject, did not then receive from the smelters a price for their ores adequate to the value of the metal they contained, no more than 45,000*l.* a-year. And we have found this produce increased, at the early part of the present century, to the annual quantity of near 80,000 tons of ore, yielding more than 7000 tons of fine copper, worth to the miners an annual sum little short of 1,000,000*l.*

The copper mines now working in Cornwall and Devon may be known from the following list, which contains such only as are more or less productive, and does not include such as make no returns, but may, notwithstanding, be prosecuting with a view to future discovery, many of which kind were stated in the former account of the mines working in Cornwall in 1798.

By referring to that statement, we shall find the productive mines to be forty in number, and the unproductive to amount to thirty-six.

The following list will be found to contain sixty-one productive mines, with the quantity of ores estimated from the account of sales at the ticketings, where the computed weight of each parcel of ore is stated, and the exact quantity determined after the sale has taken place.

It is possible that some few mines may exist which do not appear in this list, and which sell their ores by private contract, but they are not important.

We subjoin to the list the Devon mines, with their quantities of ore, taking account, as in Cornwall, of such only as are productive; and the whole is made up to the end of December 1811.

A list of Copper Mines, with the Quantities of Ore offered for Sale at the Ticketings from each, in the Year 1811.

In the county of Cornwall there are 61 mines.

Names of the Mines.	Tons of Ore.
Wheal Alfred -	
Dolcoath -	
Wheal Unity -	
Wheal Abraham -	
Poldice -	
Wheal Damsel -	
Gunnis Lake -	
West Wheal Fortune -	
Wheal Towan -	
Wheal Fanny -	
Crennis -	
Oatfield -	
Treskirby -	
Wheal Gorland -	
Cook's Kitchen -	
Crenver -	
Tin Croft -	
North Downs -	
Wheal Friendship -	
Wheal Jewel -	
Wheal Virgin -	
Saint George -	
United Mines -	
West Wheal Virgin -	
Wheal Fortune -	
Wheal Quick -	
Camborne Vean -	
Wheal Chance -	
Wheal Spinster -	

Carried over 63,636

Brought over	63,636
Wheal Neptunc - - -	539
Wheal Gons - - -	443
Godolphin - - -	411
Creegbraws - - -	316
Trefavcan - - -	311
Nangiles - - -	266
Botallack - - -	244
Penberthy Crofts - - -	212
Wheal Clinton - - -	209
Chacewater - - -	204
Wheal Bassett - - -	204
Wheal Dolphin - - -	183
Wheal Druid - - -	177
United Hills - - -	177
Benner Downs - - -	175
Wheal Maid - - -	151
Wheal Strawberry - - -	148
Union - - -	146
Wheal Music - - -	145
Wheal Sparnon - - -	97
Wheal Maudlin - - -	95
Wheal Margaret - - -	90
Wheal Lushington - - -	81
Unanimity - - -	49
Wheal Squire - - -	45
Relistian - - -	41
Wheal Spearn - - -	20
Wheal Mary - - -	20
Trenowith - - -	18
Wheal Freedom - - -	16
Roskear - - -	10
Rosewarne - - -	7
	<hr/> 68,886

In the county of Devon seven Mines.

Wheal Friendship - - -	1102
Wheal Crebor (<i>Tavistock Canal</i>) - - -	1308
Wheal Crowndale - - -	863
East Crowndale - - -	913
Ding Dong - - -	250
Wheal Hope - - -	6
Wheal Huckworthy - - -	10
	<hr/> 4,452
	<hr/> Tons 73 338

Hence it will appear, that the copper mines have of late been declining in their produce, which is to be referred to the general state of trade rendering the price of the metal unequal to the charge of producing it.

The present value of copper, as was observed in a former part of this article, is as low as it was 100 years ago, and we may account for the possibility of this happening without absolute ruin to the mines, by the facilities which the great improvements in all the various operations of mining have given for lessening manual labour and consequent expence.

This very improvement has, however, contributed to a more rapid exhaustion of the ores, and though discovery has hitherto in this district kept pace with the gradual waste, yet it is impossible not to foresee that as the country is even now very fully explored, a time must arrive when the quantity of metal produced will grow less, and the price in consequence must advance.

This period we conceive is not so distant as some may imagine, but it is a subject not easily reduced to any very probable calculation.

The history of the mining of a particular district would naturally lead to an interesting enquiry on this subject, and to the discussion on the probability of a future and continuing supply of the metals which the bowels of the earth have hitherto yielded so abundantly. As this question regards one country, it may be assumed that the supply must have its limits; as it regards the whole world, it becomes difficult even to conceive what extent or number of deposits of metal may exist.

That certain districts may become exhausted is more than probable, but others now unexplored by the hand of man may be found. New powers, as far surpassing those of the steam engine as they did all former ones, may give the means of penetrating the earth to depths now unattainable, and veins may hereafter be followed to situations which are forbidden at present by the value of their produce or the want of sufficient exertion.

The stores which the earth yields from its bowels are unlike those which its surface produces; the former are limited and are not renewed, the latter are constantly produced by the encouraging hand of industry. The one are gradually exhausting, and seem to demand frugality in their expenditure, the other grow and increase in proportion to our care and exertion.

The result of a gradual exhaustion of mines now existing seems likely to be this; at first the price of metals will increase in proportion to their scarcity, this advance in value will lead to a greater produce by new efforts even in the districts which are exhausting, and after these begin again to fail, which they will do more rapidly from the increased exhaustion, new districts will be sought after, and perhaps uncultivated countries even become peopled by the want of what is now become so necessary to human life.

The variation in these affairs may at some time make material changes in the state of civilization, a position which will not be denied by those who duly consider the effects that the stores of coal and metal have had on the prosperity of Britain.

MINING Processes, according to the practice of the mineral districts of Cornwall and Devon.

The means pursued for the discovery of veins containing metal, and the appearances which serve as indications of the probable quantity which may be found in them, are treated of in a former article. See *LODE*.

The works which follow the discovery are at first but simple and limited, but they increase afterwards in proportion as the prospects of future success become more certain; or, on the contrary, they are discontinued when the trial offers but little encouragement to proceed with the adventure.

By a reference to the article above quoted, it will be understood how the deposits of metal are usually situated in the veins; and as the miner's object in his first operations is to get at some shoot or bunch of ore as quickly as possible, and to open as much of the lode as he conveniently can, the most promising part on the surface is chosen for the commencement of a *shaft*, which is either sunk upon the vein so as to follow its dip or underlay, or otherwise is carried down perpendicularly from some spot on the side to which it dips, so as to intersect it at a given depth, and then is usually called an *underlayer*.

As water is commonly soon met with in such quantities as to impede the workmen, means for removing it must be provided, and it speedily becomes necessary to take steps for this purpose. Where the elevation of the ground will admit of an *adit* or water-level being made, this is usually first had recourse to, particularly when it may be obtained by driving

a moderate distance, or when it can be pursued on the course of the lode, and so serve the double purpose of a drain and a level for trying the appearances of the vein.

When the shaft becomes deeper than the adit, or indeed when the latter cannot well be had, machinery to draw out the water is erected and employed, such as steam-engines, or over-shot water-wheels where streams to drive them can be obtained: in both cases these engines are employed to work pumps to raise the water.

As soon as a shaft is sunk sufficiently deep, and it becomes desirable to pursue the lode horizontally, it is stopped for a time, and a level is commenced on each side of it, and this is usually continued in two opposite directions upon the course of the vein. The ends of this level being driven out of the way of the shaft, sinking may again be undertaken, and continued until it is deemed proper to drive another level; and thus a succession of these galleries or drifts are opened under each other, and the vein is divided into parallel portions, which are left to be worked for the ore contained therein, and which portions are called *bucks*.

New openings to the surface from these levels are afterwards made by sinking more shafts at proper distances, and communications from one level to another are formed by sinking a kind of small underground shaft, called a *winze*, probably because the only machine employed in their execution for hauling the stuff is the common windlass, which, in Cornwall, has generally the same abbreviated or corrupt appellation.

When a mine is put into this state, and any quantity of ore discovered, proper engines provided with sufficient power to admit the constant deepening of the mine by keeping the bottom of the engine shaft, called the *sump*, dry, so as to be regularly sinking: when the ventilation is completed by proper means for that purpose, and machines constructed for hauling up the ores and waste to the surface called *whims*, a mine, in the technical language of Cornwall, is said to be in due course of working.

The agents who attend daily to the works are called *captains*; they contract with the different classes of *miners*, and direct the operations, under the orders either of the principal adventurers, or a manager appointed by them.

The shafts and levels are kept regularly sinking and driving to lead to further discovery, or to open more of the lode for working, and the parts of the vein or lode left between the passages thus made are worked away, where the ore will pay the expence of so doing, by men, who contract for this work within certain limits, being paid a proportion of the value when merchantable, which is called a *tribute*, and which varies with the degrees of facility with which the ore can be procured, either from the different states of richness of the lode, or the hardness or softness of the rock which must be broken to obtain it.

The ore is usually conveyed in wheelbarrows through the levels under ground by boys to the nearest shaft, and there raised in buckets or *libbles* to the surface. These kibbles are wound up by the whims, which are turned either by horses, steam, or water.

In preparing the ores for smelting, a variety of processes is employed, which require the labour of many hands; these are carried on upon the surface, and chiefly by women and children. The object being to separate from the ore both the stony and sparry waste, and the mundic or other useless metallic mixtures with which it is combined, considerable skill is required, from the different specific gravities

of the various substances, which render it impossible by mere washing to separate the ores entirely from the different mixtures which accompany it.

To dress ore properly, it is essential that the whole should first be brought into such a state of division, that the different parts may be separated by washing or sifting: and, therefore, the richer the state in which the whole is raised from under ground, the less the labour required in breaking or stamping. The better parts of the ore are broken to a proper size for smelting, either by flat hammers, or, as is now usual in the mines in Devon, by iron cylinders driven by water. For the coarser parts much more labour is required in stamping, sifting, and washing, the particular detail of which will be found under the article *ORE*.

The stamping-mills, and other apparatus for dressing the ores, are usually fixed as near the mouths of the shafts on the surface as possible, consistently with the power of leading streams of water to them. And plots, or *floors*, are prepared near them for receiving the merchantable ores until they are sold to the smelting companies.

The management of these processes is usually confided to a *dresser* or *grafs captain*, who regulates the whole, the expence being borne by the men who raise the ore on tribute, who take their proportion of the value according to the amount of the sales, and, therefore, pay every previous charge.

The erections on the surface of a mine comprize, besides steam or water-engines, whims, stamping-mills, and sheds on the dressing floors, a suitable counting-house for the captains and clerks, where the people are paid monthly, and the bargains or contracts made by a kind of public auction. A forge, or blacksmith's shop, accommodated to the extent of the mine, where men are generally at work by night as well as by day, to sharpen tools as well as to make or repair the iron-work of the different engines. A carpenter's shop, or *timber-house*, for work of that description, which is always going on to a considerable extent.

From the account given in the *History of MINING*, and the statement of the disbursements and returns there exhibited of all the concerns of that description in Cornwall and Devon, it may be seen how extensive some of them are in that respect. It may further be here observed that great depth has been attained in many of the older ones; in Dolcoath, which we believe is rather the deepest, the lowest part is somewhat more than 220 fathoms from the surface. Some individual mines in Cornwall employ near 1000 persons, and have several steam-engines working for the different purposes of pumping the water and raising the ore. In the county of Devon, streams of water being at hand, large over-shot wheels are employed for working the pumps, and several have been erected of late years equal in power to the larger steam-engines. Within a very late period, the same economical means have been applied in a very ingenious manner to the winding up the ores from under ground, which, from the crookedness of the shafts of copper mines, was a work of more difficulty than might at first appear.

We propose to give more detailed accounts of the processes of breaking, raising, and dressing the *Ores*, under the article bearing that title; and shall describe the operations of sinking shafts and driving the levels from them under the head of *SHAFT*. The pump-work of mines, and the means for ventilating drifts, will be treated of in their proper places.

MINERALOGY.

PLATE I.

MINING

Fig. 1.



Fig. 2.

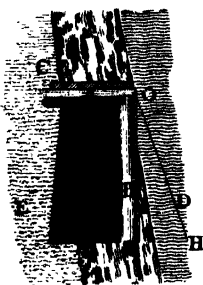


Fig. 3.

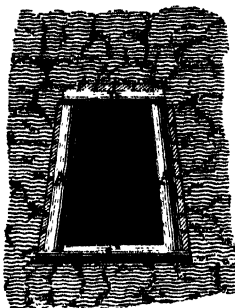


Fig. 4.

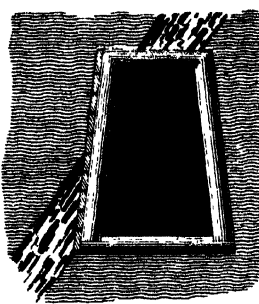


Fig. 5.

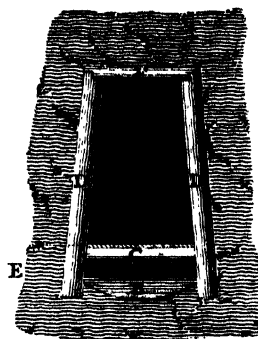


Fig. 8.

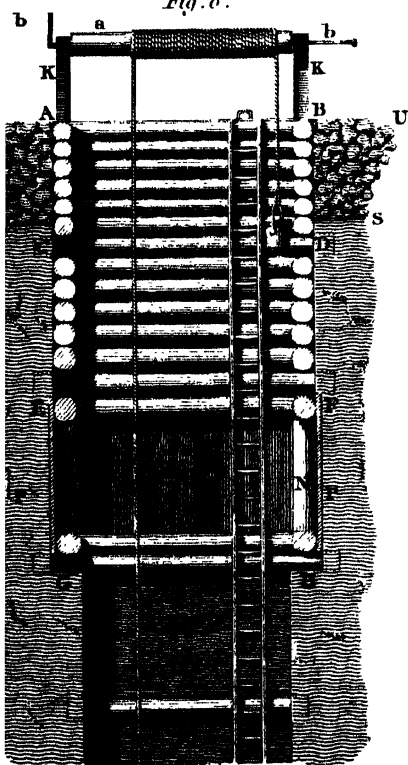


Fig. 7.

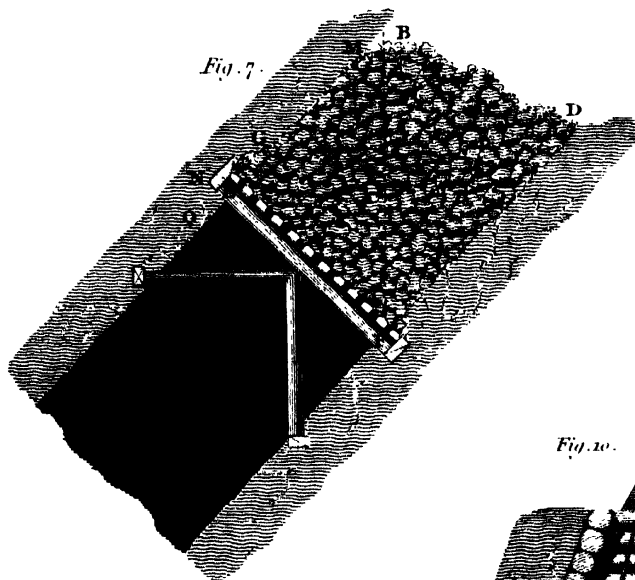


Fig. 6.

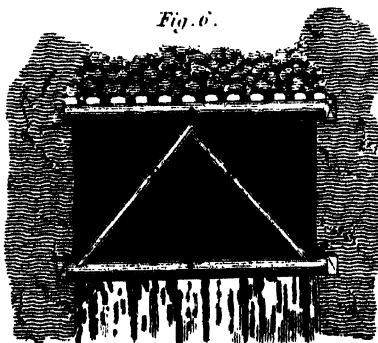


Fig. 9.

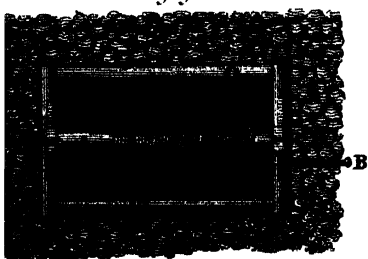
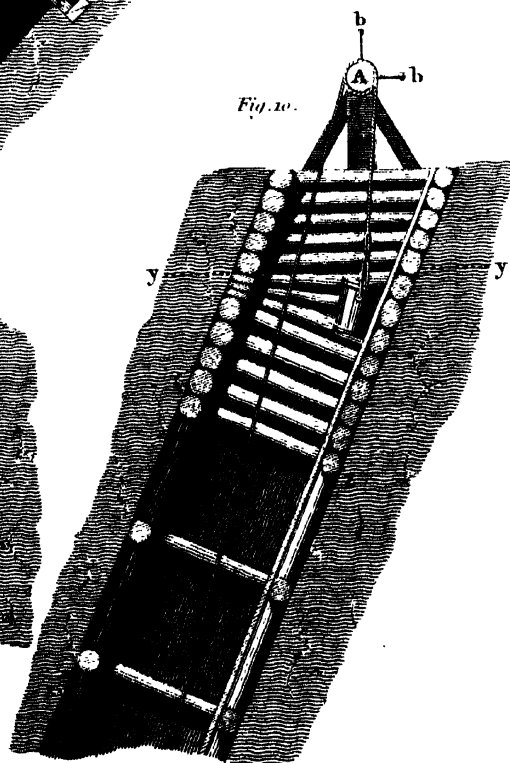


Fig. 10.



Molosses

MOLOSSES, MOLASSES, or *Melasses*, that gross, yet fluid matter remaining of sugar, after refining, and which no boiling will bring to a consistence more solid than that of syrup; hence also called *syrup of sugar*.

In the manufacture of sugar in the West Indies, the molosses, not improperly called the treacle of sugar, is obtained by the following process. The curing-house, which is a large airy building, is provided with a capacious molosses cistern, the sides of which are sloped and lined with tarred or boards. Over this cistern there is a frame of massy joist work without boarding. On the joists of this frame empty hogsheds without headings are ranged. In the bottoms of these hogsheds eight or ten holes are bored, through each of which the stalk of a plantain leaf is thrust, six or eight inches below the joists, and which is long enough to stand upright above the top of the hogshed. Into these hogsheds, the mass from the cooler is put, which is called *potting*; and the molosses drains through the spongy stalk and drops into the cistern, from which it is occasionally taken for distillation. For other particulars, see the article SUGAR; and particularly the method of *claying* sugar.

The term *molasses* has been used to denote the sediment of one kind of sugar called *chypre*, or brown sugar, which is the refuse of other sugars not to be whitened, or reduced into loaves. (See SUGAR.) Molosses have been much used in Holland among poor people, for the preparation of tobacco, and also instead of sugar.

MOLOSSES, Artificial. There has been found a method of making molosses from apples, without the addition of sugar. The apple that succeeds best in this operation is the summer-sweetening of a middle size, pleasant to the taste, and so full

of juice, that seven bushels will yield a barrel of cyder. The manner of making it is this: the apples are to be ground and pressed, then the juice is to be boiled in a large copper till three quarters of it be evaporated: this will be done with a moderate fire in about six hours, with the quantity of juice above mentioned; by this time it will be of the consistence and taste as well as the colour of molosses.

This new molosses serves to all the purposes of the common kind, and is of great use in preserving cyder. Two quarts of it put into a barrel of racked cyder, will preserve it, and give it an agreeable colour.

The invention of this kind of molosses was owing to Mr. Chandler, of Woodstock, in New England, who living at a distance from the sea, and where the common molosses was very dear and scarce, provided this for the supply of his own family, and soon made the practice general among the people of the neighbourhood. It is to be observed, that this sort of apple, the sweetening, is of great use in making cyder, one of the very best kinds we know being made of it. The people in New England also feed their hogs with the fallings of their orchards of these apples; and the consequence of this is, that their pork is the finest in the world. Phil. Trans N^o 374. p. 230.

MOLOSSES Spirit, a very clean and pure spirit, much used in England, and made from molosses or common treacle dissolved in water, and fermented in the same manner as malt or the common malt-spirit. If some particular art is not used in the making of this, it will not prove so vinous as the malt-spirit, but more flat and less pungent and acid, though otherwise much cleaner tasted, as its essential oil is of a less nauseous flavour. Whence if good fresh wine lays, abounding

in tartar, be duly fermented in the solution made thin for that purpose, the spirit will by that means become much more vinous and brisk, and approach more to the nature of the foreign spirits.

After the first distilling of molosses spirits from the wash into low wines, it is to be rectified, and in the succeeding rectifications proper additions are to be made. Alkaline salts, so common in the rectifying of the malt-spirits, must be avoided in this case, as not at all suiting this spirit, and the neutral ones only must be used, such as sandiver, common decrepitated salt, sal enixum Paracelsi, and the like; but upon the whole nothing so considerable is to be expected from these salts, as from a careful rectification in *balneo Mariae*, without any other admixture; by this alone repeated two or three times with fresh water each time, the spirit will at once be made fit for the nicest uses.

Where the molosses spirit is brought to the common proof-strength, if it be found not to have enough of the vinosity in it, it will be very proper to add to it some good spiritus nitri dulcis; and if the spirit be clean worked, it may by this addition alone be made to pass on ordinary judgments for French brandy.

When newly distilled, this spirit, like all others, is colourless, and limpid as water; but our distillers always give it the same sort of yellow tinge, which the foreign spirits are found to obtain from the casks in which they are sent over. They have many ways of giving this colour extempore; but the two most in use are, either by an extract of oak-wood, or by burnt sugar.

Molosses spirit being occasionally dearer than that of malt, it is frequently met with basely adulterated with a mixture of that spirit, and indeed seldom is to be bought without some dash of it. Many have a way of mixing malt in the fermenting liquor; by this the yield of the whole is greatly increased, and the maker may assure the buyer that the spirit is pure as it ran from the worm.

England is the principal place where this spirit is made at this time: it was at one time prepared in great quantities in France, especially on the river Loire; but it has been

forbidden there under a severe penalty. In Holland also they have it not, on account of the high duty laid upon treacle in favour of their own sugar-bakers.

We meet with very little of molosses spirit reduced to the strength of alcohol or spirit of wine, though, when rectified to this state in a proper manner, it is very little inferior to the real alcohol of wine, the name of which is so well known among us, though the thing itself is perhaps never seen here. All that we call spirit of wine being no other than malt spirit reduced to an imperfect alcohol, or a spirit almost totally inflammable.

Great quantities of molosses spirit are used in the adulterating of brandy, rum, and arrack; and great quantities are used alone in the making of cherry-brandy and other drams by infusion, in all which many prefer it even to the foreign spirits.

In most of the nice cases in our compound distillery, the molosses spirit supplies the place of a pure and clean malt-spirit, which we have not yet the way of producing in the large way to advantage. Our cinnamon, citron, and other fine cordial waters, are made with it; for the malt spirit would give these a very disagreeable flavour.

There is also another use to which this spirit serves extremely well, and in which even a foreign spirit that has any remarkable flavour will not do so well; this is the making of the extemporaneous wine, which some people are so fond of. See *Extemporaneous Wine*.

It gives a yellow stain to the hands, or other substances dipped into it: and may therefore be of use in dyeing. It is possible also, that the vinegar-makers may find use for it in their way; but the most advantageous of all its uses is to the distiller himself, a quantity of it added to new treacle intended for fermentation will be of great use in the process, and increase very considerably the quantity of spirit; but the proportion in regard to the new matter must not be too great. Shaw's Essay on Distillery.

For the method of extracting spirits from molosses in the West Indies, see the article RUM.

